DESIGN CULTURE (OF) ARTIFICIAL DIGITAL TECHNOLOGY ROBOTIC
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“If Design is the Sciences of the Artificial, then how can Design theories and practices promote a better quality of life for us, humans?”

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“How must design deal with a slow culture shock of the artificial that smart objects manifest in personal or professional spaces? Which forms of business or political machines do we need to reject?”

Patrizia Marti,  
University of Siena, Italy  
“In the digital age, a new culture of design can flourish to value the complexity and uniqueness of being human, bringing aesthetics, creativity, sense making and value-oriented propositions at the forefront of technology development.”

Giuseppe Mincolelli,  
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“Data are a substantial part of our life, that we do not perceive and understand by nature. Design is called to empower humans, bridging this new phisical and cultural gap between us and our environment.”
A participated parametric design experience on humanoid robotics

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Abstract | The project hereby presented illustrates the case study of a participated parametric design workshop, where the object is a hacked version of Poppy, an open source 3D printable humanoid robot developed by Matthieu Lapeyre. Poppy is used by a large community of researchers whose focus is mainly on engineering and IT aspects of the platform development. Our activity, held in a larger dissemination event, was aimed instead at collecting data regarding users’ perception of a companion robot, caregiver robot or evil robot. Our goal is to define aesthetic principles that influence users’ appreciation and affection towards a humanoid robot. A parametric definition developed with Grasshopper 3D, easily editable thanks to a simple and intuitive interface, was used as a tool to involve users in a co-design activity which results are analyzed and presented in the following contribution.

KEYWORDS | HUMANOID ROBOTICS, PARAMETRIC DESIGN, PARTICIPATORY DESIGN,
3DPRINTING, OPEN SOURCE
1. Introduction

We are living in the era of bespoke products and personalization. This generic trend has evolved and become massive in most industries, supported by several technical developments in the world of design, such as the spread of open source tools for digital design, the development of rapid prototyping technologies and the emergence of the parametric approach in several areas of the world of the project (Manzini, 2015).

In particular, the practise of parametric design, described by the architect L. Moretti as “the relations between the dimensions dependent upon various parameters” (Bucci & Mulazzani, 2006), has spread from the architecture world to product design as new and more effective tools have been developed. Nowadays visual editors and programming tools are easier and easier to access, implement and learn; they allow designers to draw with algorithms, which can be defined as procedures that perform particular tasks through finite lists of well-defined instructions and inputs (Tedeschi, 2014).

If writing algorithms and designing with parametric tools remain prerogatives of the developer or the designer, these instruments can easily be used in participatory design experiences.

Participatory design has its roots in Scandinavian culture; the first co-design techniques have been developed there in the 1970s, but are taking upon themselves new meanings and definitions through the spreading of mass customisation in contemporary industry and the following growth of configuration tools designed to be used by end users who can thus make - usually small - design choices on the products that they are going to buy (Ciuccarelli, 2008).

Moreover, co-design techniques are very useful in the User-Centered Design process (Falcinelli, 2011). This essential practice of design is widely accepted and frequently used these days, especially in technological areas due to the fact that most likely a high-tech product, system or service will interact actively with users for which it is intended (Rizzo, 2009). Research in this field is even more important if we think of users that may not be used to interact with technological products, as in the case of elderly or people with disabilities. Speaking of interaction with technological products, it can be assumed that humanoid robots could provide the most complete experience in this respect. Therefore, it is of great importance to investigate people perception of those products, especially by weak users.

2. User Centred Robotic Design

The rapid technological growth that we are facing nowadays has highlighted issues about human-computer interaction, specifically with reference to the scope of robotics. Such dynamics open up new challenges for UX designers (Gamberini et al., 2012). While in the past the robotics scope was mainly involved in design industrial machines, in recent years we have witnessed an increasing number of social robots. The latter are able to interact, sometimes having complex relations, with human beings and other machines. They are able to learn from the environment in which they are located as from the interactions with users and to develop
A participated parametric design experience on humanoid robotics

Designing a social humanoid robot is not just the development of a consumer product as a household appliance and is not just the engineering of a body to a vocal assistance. Is a discipline that is located somewhere between the two previous ones: to create a physically tangible automaton, more or less human-like, able to act and react with a decision-making autonomy and capable to arouse complex emotions. This is not just about dealing with technical issues, but also taking into account the psychological side, considering the legal liability, evaluating social dynamics, economic viability and environmental impact. Therefore, it is necessary to place the individual at the center of the design process in order to directing research and activity to design an acceptable and accepted user experience of the interaction. Only then not just the shape but also the behaviour of social robots will be human-like and the technology will fit users’ needs.

3. Poppy, a case study

The project hereby presented illustrates the case study of a participated parametric design workshop, where the object is a humanoid robot.

Our aim is to analyze the morphological aspects of humanoid robots and the users’ perception regarding them. In order to do that, we planned an activity that would positively involve a wide audience in making design choices on a humanoid robot; in particular we worked on editing the 3D models of Poppy, which is fully available online on an open source platform developed by Matthieu Lapeyre in 2012, for his PhD thesis (Lapeyre et al., 2014).

Poppy is an 83 cm tall robot having 25 degrees of freedom and weighing 3.5 kg; it is fully 3D printable and hackable and it has a very active community surrounding the project, including universities, research institutions and private entities. Most of the research surrounding Poppy is focused on developing its engineering and IT aspects, but that was not our focus for this project. In fact, the mechanical and electronic parts remain the same, and the IT development has not been taken into consideration.

Instead, we re-designed the 3D model of Poppy’s limbs using Grasshopper, a well-known visual programming language and environment that runs within the Rhinoceros 3D CAD application.

We used texture mapping to chart arms and legs and edit them using six different shapes with a varying design and degree of hollowness; in general, the editable parameters in our model were the following:

- colour of the head
- shape of the eyes projected on the incorporated screen
- chest, shoulder and hip colours
- type and density of the texture and colour of the upper arm
- type and density of the texture and colour of the forearm
- hand and foot colours
- type and density of the texture and colour of the thigh
- type and density of the texture and colour of the shin

As the joints of arms and legs remained the same of the original model designed by Lapeyre, we created a parametric system that allows to change every single limb of the robot without affecting its functionality and stability. In theory every user can now design his unique companion robot, according to his needs and tastes.

4. Method

In this section it is described our approach to the activity, the setting and the user experience. The workshop took place during Rome Maker Faire 2019 for three days. The audience varied from families to technology amateurs and students. We used the tool of the survey to collect data about the visitors’ age, gender and education level; this way we can paint a clear picture of the results we collected. At the end of the survey we would send the image of the designed robot to the participant’s email. However, the survey took some time to be filled and many visitors, even though they found our activity engaging, decided not to complete it. In the end we collected 71 different designs for our robot; most of the participants were very young, between 5 and 12 years old.

The setting of our activity was very simple. We had a stand with a few tables where we placed some FDM printers, that we used to print in real time the pieces we needed to build our Poppy. While some of us worked on assembling and printing the robot, others were greeting the visitors and guiding them through the activity.
Before starting to design their robot, participants were asked to choose between three different scenarios: they could design a caregiver robot, a toy robot for their kids to play with or an evil one. This choice would influence all the consequent ones and already represents an interesting term of comparison: we will discuss the results in detail in the following section.

The parametric model was easily editable thanks to the simple and intuitive interface of Shapediver, an online editor specifically designed to show files generated in Grasshopper. It was enough for users to drag some sliders in order to edit colours and geometry of the model, without needing any kind of skill in 3D modeling.

In order to give a physical feedback to users, the mostly often chosen geometries were 3D printed live during the workshop. This way, the experience had an analogic development, parallel to the digital one: due to the availability of a high number of 3D printed parts, it has been possible for users to understand the physical results of their choices.

5. Results and findings

In this section we will thoroughly discuss the analysis of our data sample; as mentioned before, we collected 71 different models and surveys.
Our population sample is quite peculiar, due to the specificity of the Faire in which our activity was held. Two thirds of the participants are male, and almost half of them are very young, between 5 and 12 years old. Only 30% of the participants hold a university degree of some kind, most of them in the area of design and engineering.

The companion robot was the most selected scenario, by 45% of the population; the caregiver robot was selected by another 30%, and the remaining 25% designed the evil robot. We will now analyze every scenario.

5.1 SCENARIO #1 - Design a robot to give to your son as a present for Christmas

![Image of distribution chart](image)

*Figure 2. The chart shows the sample distribution of users in the first scenario grouped by age.*

A first insight that we can highlight is that most of the users who chose this scenario were very young. We can argue that kids are fascinated by the idea to play and interact with a humanoid robot and are not influenced by adults’ suspicions and distrusts towards artificial beings.
Regarding the face, 41% of the participants chose big rounded eyes for their project; they clearly aimed to paint a friendly and kind expression on Poppy's screen.

Figure 3. The visualization shows the users choices regarding the design of the robot for the first scenario.

An interesting reflection can be made on colour choice: kids have a tendency to use all the colours at their disposal, and this appears to be evident in our analysis. Even though there is a prominence of yellow and blue, our toy robots present an average of 4.7 colours used in the same model. We also noticed a tendency that could be expected: girls make a higher use of pink in their design.
Figure 4. The picture presents the archetype of robot designed by users for the first scenario.

Young users were playing a lot with colours and shape of the texture but kept the density of it at an average level. The chosen textures were mainly quite hollow, generating robots that appear to be lightweight but also sturdy and strong.
5.2 SCENARIO #2 - Design the robot that will take care of you when you will be old

![SCENARIO #2](image)

Figure 5. The chart shows the sample distribution of users in the second scenario grouped by age.

This scenario shows a pike of appreciation by 36+ years old users. This may indicate an interest in the market of companion and caregiving robots by a population of adults that will in the future need assistance in their homes. However, we also recall an interesting trend of kids wanting to design robots for their grandparents, which again shows that youngsters are not intimidated at all by artificial beings that may live with them.
Figure 6. The visualization shows the users choices regarding the design of the robot for the second scenario.

The most selected eyes were again big and rounded, but there is a very different trend in colour choice. In fact, main selected colours in this case are white and black, with an average of less than 4 colours used in a design. This trend is in line with products on the market. Other colours often selected as accent for the design were mainly blue and yellow.
In this scenario we saw a slightly higher degree of density and complexity in the chosen textures, but the most interesting trend regards the hollowness of it: this is the scenario in which Poppy’s limbs are lighter. This may indicate that users perceive caregiving robots as life companions who don’t need to have a big and intimidating body, but rather a light and tiny structure, easily adaptable to confined environments such as private houses and hospitals.
5.3 SCENARIO #3 - Design the evil robot that is able to submit humanity

![Chart showing user distribution by age for SCENARIO #3.](image)

**Figure 8.** The chart shows the sample distribution of users in the third scenario grouped by age.

This scenario was the least selected; most of the participants that chose it were teenagers enjoying the idea of designing an evil character. Almost 60% of the designs present a stripe in substitution of the eyes; we believe that our users were recalling a recurrent iconographic choice made in movies.
A participated parametric design experience on humanoid robotics

Figure 9. The visualization shows the users choices regarding the design of the robot for the third scenario.

Regarding colour choice, this is the scenario where the average of used colours in a design is smaller: only 2.8%. The most selected colours are black and red.
For what concerns the structure of the limbs, this scenario presents quite complex and dense textures, with a slight preference for the studded texture. Plus, this is the scenario with the less hollow structure.

In general, the evil robot appears to have a clear and well-defined iconography in the imagination of our participants, who surely recall movie and videogame characters when making design choices. Compared to the other scenarios, this is the one that mostly gave us results that we could easily expect to receive.
6. Conclusions

During the period of the faire, visitors have shown interest and involvement in our proposal; direct feedback confirmed that the public is fascinated and curious about the field of humanoid robotics and some of the people we talked to also declared that the possibility of having a companion personalized on their specific needs and tastes was very compelling to them.

We believe that the positive feedback also lies in the innovative method of data gathering and co-design that we experimented. The use of a simple digital platform to edit the project was supported by physical models of the robot and by functioning 3D printers. The participants thus had complete control and understanding of the design process, a situation that is not to be taken for granted in many participatory design experiences. Further developments of the project will hopefully take into account the possibility to program the robot to perform simple tasks, in order to give a complete formative experience to the users, especially the youngest.

In general, we have been able to confirm our hypothesis on people’s perception of humanoid robots. In particular, we found that colours hold great importance in the perception of the goodness or evilness of a robot; most of the design choices were made, as expected, based on memories of popular archetypes seen in movies and videogames, especially with regard to facial expression and colour; lightness and small size seem to be important features for companion and caregiving robots, while sturdiness obviously make the user feel intimidated and inferior.

The data sample that we were able to collect has proven to be very useful for our analysis of Human - Robot Interaction patterns. Future experiences will be based on similar approaches, with the goal to find a faster way to collect information, in order not to lose data of participants that had few time at their disposal.

References


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A systemic vision for the common good: \textit{|C|A|S|E|} Goods Mobility in the fourth industrial revolution.

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\textbf{Abstract} | The design research is developed inside the urban mobility of the goods. It is named \textit{|C|A|S|E|} as the system takes as basic values and innovations the followings: the process innovation introduced by the 4\textsuperscript{th} Industrial Revolution that allows inside mobility the interconnection of vehicles and surroundings (.C. Connected); the “rethinking” of vehicles as automated ones (.A. Autonomous); the value of spreading good practice of sharing (.S. Shared); the use of electrical sources of energy (.E. Renewable Energy).

The innovation proposed by the system as strategic participations are introduced by considering the new advanced logistic offered to the B2B and B2C as change opportunity. Inside it all the elements are guardians of a primary value that is the economic growth of territory for the development of a civil economy that put importance to the design and recognize the ethic of work as elements of real innovation.

\textbf{KEYWORDS} | SYSTEMIC DESIGN, COMPLEXITY STRATEGY, DESIGN SYSTEM, ENHANCING URBAN SPACES, CREATIVE COMMUNITIES
1. The macro-system \(\text{C|A|S|E}\): introduction

The design research is developed inside the urban mobility of the goods. It is named \(\text{C|A|S|E}\) as the system takes as basic values and innovations the followings:

- the process innovation introduced by the 4° Industrial Revolution that allows inside mobility the interconnection of vehicles and surroundings (.C. Connected);
- the “rethinking” of vehicles as automated ones (.A. Autonomous);
- the value of spreading good practice of sharing (.S. Shared);
- the use of electrical sources of energy (.E. Renewable Energy).

The macro system is developed on systemic interactions based on macro values objectives so it enhance and helps the growing of the collectivities. The scale to measure the kind of acting inside the collectivity is expressed by the double side reading formula: me>we>they. This value base of the research is very important because we think that the deep meaning of the design has to be oriented on the ethical order.

The innovation proposed by the system as strategic participations are introduced by considering the new advanced logistic offered to the B2B and B2C as change opportunity.

A co-robot in each scenario takes care of good relationship acting in the system, aiming to learn and teach how to preserve the life among time of the system itself.

In the macro system we are designing, the active community is at the centre of it and a new interpretation of sharing is given as development and common aid to civil and political economy that shelter both companies and customers/users (Figure 5).

The joining of a physical network with a digital one creates an elected community that shares values of social development. This new territory created enhances the design and distributions of new products for the future.

This system is designed to be able to continuously renew itself and is capable of including all the elements not excluding the weak in it.

Inside it all the elements are guardians of a primary value that is the economic growth of territory for the development of a civil economy that put importance to the design and recognize the ethic of work as elements of real innovation.
2. The macro-system |C|A|S|E|: the systemic approach.

To create the design concepts we defined which are the innovation strategic objectives, in three range of functionality, related to:

- User/Receiver;
- Logistic between B2B and B2C;
- Delivery between B2B and B2C.

This conceptual base allowed us to identify by main phases the concept proposals divided in the four interrelated scenarios |C|A|S|E|.

Each scenarios develops a system that has two different scale dimensions for products and service design, one related to the objects (/Polo A) and the other related to places (/Polo B):

- **C. connected goods mobility** _ the New Street Appliance_ scenario becomes the system called **Promoting Radar** characterized by the slogan 'A continuous unveiling of possibilities', declining the product / service concepts between two scale dimensions: the (Polo A / object) **access point _ Collector Totem** characterized by the slogan 'A lighthouse to rediscover the experience of places' and the (Polo B / place) **mall _ Revealing Labyrinth** characterized by the slogan 'A lens to orientate yourself in a changing context';

- **A. autonomous goods mobility** _ the New Way of Acting_ scenario becomes the system called **Trails in Action _ facilitated significant purchases** characterized by the slogan Tuned and on the go, from choice to delivery', declining the product / service concepts between two scale dimensions: the (Polo A / object) **helper robot _ Active Shade / listening and proactive shadow** characterized by the slogan 'The memory of worthwhile' and the (Polo B / place) **vehicle robot _ Manta Flying Delivery / the flying drone solver of deliveries** characterized by the slogan' Deliveries accomplished without domicile ';

- **S. shared goods mobility** _ the scenario New Domestic Appliance_ becomes the system called **Solidarity Colony** characterized by the slogan 'The domestic flow of things', declining the product / service concepts between two scale dimensions: the (Polo A / object) **domestic device _ Biorhythm of Purchases** characterized by the slogan 'From desire the purchase choice' and the (Polo B / place) **domestic sharing _ The Library of Things** characterized by the slogan 'Shared Experience';

- **E. electric goods mobility** _ the scenario New Way for a Sustainable Growth_ becomes the system called **Urban circuit for eco-deliveries** characterized by the slogan 'Sustainability in motion', declining the product / service concepts between two scale dimensions: the (Polo A / object) **Cargo-Bike and Cargo-Tram _ Eco-deliveries by Tram and Bike** characterized by the slogan 'Connect actual change actions’ and the (Polo B / place) **Cargo-Retail _ Market anywhere on demand** characterized by the slogan' Vital strategies rooted inside the Territories'.
3. The macro-system |C|A|S|E| : the first three interrelated system.

3.1 The system ‘New Street Appliance _ Promoting Radar’ for the scenario |C| ‘Connected goods mobility’: scenario and main goals.

The system goal is to offer new purchasing experiences of goods capable of an enrichment of the user thanks to an offer of goods that represent a real possibility of choice and capable of the promotion of the local manufacturing companies.

The system is developed all around the user choices so that he has not only a passive role of buyer. The user is called to share the values of economic growth, as he is an active part of the system that discover and choose what is really valuable to him.

The purchasing experience proposed is declined in two different scales: from one side the discovery of a designed place the Revealing Labyrinth /mall, where the interaction takes place as a guided exploration of different purchasing zones; from the other side a designed object that has access point functions structured as a Collector Totem /access point. The Totem has compartments for the delivery and the return of goods but allows also a advantageous exchange thanks to the promotional compartments designed to enhances goods suitable for the specific user profile.

If the Revealing Labyrinth /mall concentrates more sales areas on it, and proposes a specific path for the user, the Collector Totem /access point is widely distributed in the places of a neighbourhood.

The system through the use of metadata acts like a radar that can promote local manufacturing companies of each specific district of the city allowing this micro-local companies a real B2C opportunities and support.

The most important phases for the system New Street Appliance / Promoting Radar scenario are:

- the Promotion of companies that is the main phase for both the Revealing Labyrinth /mall and the Collector Totem /access point (Figure 1), as it allows a visibility opportunity for the new and old local manufacturing companies;
- the Management of big data as metadata, to offer a personalized service with a wide option of choices responding to the user needs;
- the Purchase facilitation, to make easy the experience by adapting it to the needs of the user;
- the B2C Company support, the user can find inside the network of companies that apply to the system, a fertile pace of ethical purchase and conscious choices, helping the growth of the territorial economical identity.
- the Delivery, in a way that support the pickup service;
A systemic vision for the common good: CASE Goods Mobility in the fourth industrial revolution.

- the **Return** aimed to develop advantageous relationship that creates trust in the purchasing experience;
- the **Review**, and important phase for the relationship between the manufacturing company and user that allows the system to develop by granting an high standard of experience.

*Figure 01: ‘New Street Appliance’ system — Pole A / object ‘access point — Collector Totem’ — Map: main phases and link to others systems poles.*
3.2 The system ‘New Way of Acting /Trials in action’ for the scenario |A| “Autonomous goods mobility”: scenario and main goals.

In this system we are going to define, the needs and desires of the people are in the centre to help the consumption of significant goods.

The union between automated interactive devices with IoT logic and services to facilitate the Promotion, Selection and Delivery of the goods phases, helps the creations of a new way of acting and competing in the human needs complexity and in the consumption related to them, with the aiming of creating an increase in the offers useful for the economical development of the local district companies, and in response to that rate of unexpected events that are part of everyday life.

This system acts like a Shadow that knows the user and gives to him advices. It moves like a Manta that ‘dance’ sinuously in a network of relationship creating new fluxes and connecting people, goods and companies (Figure 2).

In the intervention dimension aimed at the Person (scale dimension Polo A / object), the system proposes the concept of a personal assistant ‘robot helper _ Active Shade’, whose symbolic node is (shown on the map as) the ‘image of a ‘Gift package from which an anthropomorphic shadow departs’ which is outlined on the characteristics of the user to give him a shopping experience based on a choice between possible goods offered to be tested periodically as possible proposal according to his profile. Only those that are really appreciated will be purchased. The connection with the ‘New Street Appliance / Promoting Radar’ (Polo A / object) access point _ Collector Totem is of relevance.

The concept intent of the product service Active Shade / listening and proactive Shadow is expressed by the value phrase: ‘From the desire the purchase choice’ (Figure 3).

In the intervention dimension aimed at the territories, (scale dimension Polo B / place), the system proposes the concept of a co-robot vehicle robot _ Manta flying delivery / the flying drone solver in deliveries, whose symbolic node is (shown on the map as) the image of a ‘Manta in flight', a biomorphic flying drone that evokes the animal's agility in moving between water and sky and the possibility thanks to its dancing performance to interact empathically with the user, tracing the recipient and performing therefore deliveries where, following unforeseen circumstances, a new address is more useful to the user. The connection with the ‘New Street Appliance / Promoting Radar’ (Polo A / object) access Point _ collector Totem is of relevance.

The concept intent of the product / service Manta flying delivery / the flying drone solver in deliveries is expressed by the value phrase: 'Deliveries accomplished without domicile' (Figure 00).

The value scenario identifies the ‘New Way of Acting’ system as ‘facilitated significant purchases’, and is overall described by a synthesis of the two poles, whose symbolic node is
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the image of a composition of ‘Trails in action’ a dimension of the human acting where ‘the world’ is depicted between the ‘Sky with the Flights’ and the ‘Earth with the Shadows’. The dialog of the two creates a new way of accessing the goods to experience real knowledge and only if the consequent is considered valid confirm the purchase.

The slogan that identifies the Values (quality and action) of this system is: ‘Materialising a good that can be owned before the real purchase’ (Figure 4).

![Image of system map](Figure 02: The system ‘New Way of Acting’ for the scenario |A| ‘Autonomous goods mobility’ | System Map: main phases for each of its poles and link to others systems.)
Figure 03: ‘New Way of Acting’ system _ Pole A / object ‘helper robot _ Active Shade’ _ Map: main phases and link to others systems poles.

Figure 04: ‘New Way of Acting’ system _ Pole B / place ‘vehicle robot _ Manta Flying Delivery’ _ Map: main phases and link to others systems poles.
3.3 The system **“New Domestic Appliance”** for the scenario |S| “Shared goods mobility”: scenario and goals.

In short, a scenario is outlined for the ‘Solidarity Colony’ system, in which the pivotal stages of innovation - primarily of purchasing management with an extension to the sharing and exchange of things (from possession of objects to use of their services - through a subscription service), together with facilitating actions in the delivery/collection and in prolonged use practices (maintenance, repair, reuse), are (Figure 6, Figure 7, Figure 8):

- **The Management of big data as metadata** allows the classification of objects, matching needs and the offer inside the community of the ‘Solidarity Colony’. This match is made by the subscription to the ‘The Library of Things’ where there are also small companies and craftsman as members. The participation to the system is aided by the ‘Biorhythm of Purchases’, a domestic device with IoT technologies that filters the availability of the goods using the user’s defined parameters and the requests of that period, regulating the sharing/borrowing or purchasing of the goods. The ‘Solidarity Colony’ is a community capable of requesting a specific manufacturing of goods by certifying their purchase (Design on Demand, Design for Sharing of goods and services).

- **Review and Monitoring.** The reviews of goods and the monitoring on all the stages of the service are the base for a good quality and developing of the system. The user is a active part of the system when he not also provide a review but he also gives information on way of use and good practice because he helps other users and promotes the available goods. The manufacturing company is an active part too when it provides maintenance and restoration of the goods and provides information about the production methods and material used (values of sustainability and ethics). The ‘Solidarity Colony’ is a community capable of testing new products for the manufacturing company and can became a testimonial for the companies’ products.

- **Goods correlation and choice support.** The ‘Solidarity Colony’ system modulates the supply of goods in circulation on the basis of data, which over time constitute a real capital with which to respond to the scheduled needs of its subscribers and with which request and promote new products on the basis of what is vital in the community itself. Users and companies exchange goods in a fluid way: everyone has access to a great variety of things, much wider than it would be in their private sphere. The solidarity and community spirit of the system circulates objects and skills, transmits security and changes the way of seeing things: from simple objects (*objectum* ‘that goes against’) to sharing opportunities and useful purchases. The owner and the consumer leave room for a wider dimension, of user and supporter.
Figure 05: The system ‘New Domestic Appliance’ for the scenario |S| ‘Shared goods mobility’
Visual Map: main concept and link to others systems.

Figure 06: The system ‘New Domestic Appliance’ for the scenario |S| ‘Shared goods mobility’
Map: diagram main phases and link to others systems.
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Figure 07: ‘New Domestic Appliance’ system / Pole A / object ‘domestic device _ Biorhythm of Purchases’ / Map: main phases and link to others systems poles.

Figure 08: ‘New Domestic Appliance’ system / Pole B / place ‘domestic sharing _ The Library of Things’ / Map: main phases and link to others systems poles.
4. The macro-system |C|A|S|E| : the last of the four interrelated systems.

4.1 The system ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’: focus on scenario.

The system is characterized by synergy of different transport solutions: Cargo Bike, Cargo Tram, Cargo Retail. All this solutions contribute at the goods delivery and create new functionality for the system. They are all green powered and will moves through the city by existing paths (Figure 9).

These vehicles are designed to be modular, complementary and integrated and will be assisted by static elements (goods interchange stations, pick-up boxes).

The system goals are to enhance local identity and strengthen the social relationship. To achieve this, the system wants to be a supporter of the good environmental practice by becoming an Itinerant exhibitor of them.

The goods on sale will respect the environmental sustainability and will be promoted by the possibility for the user to be aware of their manufacturing origins. To avoid the waste of perishable goods they’ll be reallocated when next to their expiry dates. The system can also be used to collect old goods at end of life stages.

The system we are designing has at his core the enhancement of local manufacturing companies by creating an organic exchange characterized by active relations inside all the elements of the system.

The interconnection of the different services available wants to create a ‘on the go sustainability’ for the development of a flexible system capable of understanding and adapting to the changes.

4.2 The system ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’: main goals.

In short, a scenario is outlined for the ‘New Way for a Sustainable Growth’ system - new ways of conceiving the ‘Cargo-Bike and Cargo-Tram’ and ‘Cargo-Retail’ -, in which the key phases of innovation mainly focused on goods delivery with extension to the sale, together with support actions and testimony of eco-sustainable practices, are:

- **Delivery / Pick Up**. This functions are fulfilled by special closed structures offered by the cargo Tram for the collection of goods and door do door delivery made through cargo Bike;

- **Collection**. All the poles of the system (cargo bike/ tram /retail) offer a collection point for packaging and recyclable waste;
• **Correlation of goods** and **Promotion of business**. These phases are ensured by the selections of goods that respects eco-friendly and civil economy requirements. These products are made available to the consumer thanks to the moving market offered by the **Cargo-Trim** and thanks to the downstairs market offered also on request by the **Cargo-Retail**;

• **Review**. This phase is dedicated to the relationship with the customers/users. Thanks to the IoT technologies the system can evolve by continuously granting a high quality and performance offered.

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**Figure 09** _The system ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’_ — Visual Map: main concept and link to others systems.

**4.3 The system ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’: main results related to user / receiver._

The ‘**Choice, Monitoring, Pick Up, Evaluation and Review**’ phases emerged from the area of functions dedicated to the "**User / Receiver**".
The Pole A1 ‘Cargo-Bike / Connecting actions of effective change’ assumes a systematic delivery of goods destined to a client that wants to be informed in order to take conscious choices. To achieve this the product/service concept is focused in the following phases of the system (Figure 10):

- **Choice**: the concept wants to be an itinerant showcase of different high quality goods of the local manufacturing companies, especially for commodities, short life products and refillable package products;
- **Pick Up**: the concept allows a new formula of booking neighbourhood delivery with the possibility of giving back the packaging of the purchased goods. The concept has a designed pulled module for a proper collection and storage of this items.

![Figure 10: System ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’ _ Pole A1 ‘Cargo-Bike / Connecting actions of effective change’ _ Map : main phases and link to others systems poles.](image-url)
A systemic vision for the common good: CAS|E Goods Mobility in the fourth industrial revolution.

The Pole A2 ‘Cargo-Tram/ Connecting actions of effective change’ assumes for the following phases:

- Pick Up: A connection with the system ‘New Street Appliance / Promoting Radar’ (Polo A / object) Access Point _ Collector Totem allows the presence on the tram docks of controlled access Storage units for the picking up of the purchased goods. This access points that works all day long are distributed along the Tram railways circuit and the user can choose freely the preferred dock for the picking up of his purchase (Figure 11).

The product concept is: a Tram dock equipped with a Pick Up Units area for the customers, an Exchange area for the modules containers accessible by the Cargo-Bike for the door to door delivery and by the Cargo-Retail for the itinerant showcase modules.

The service concept is: a web application for the access to the storage units by a secure code sent to the user. A personal card will be also available to easily access to the units interface to improve the user experience.

The storage unit became a place where the user cannot only pick up the goods but also storage items to be shared connecting with the system ‘New Domestic Appliance / Solidarity Colony’ (Polo B / place) ‘domestic sharing _ The Library of Things’.

- Evaluation and Review: The system operates in order to enhancing the valuations stage and wants to collect advices for a real involvement and continuous upgrade of the delivery and purchase offer. Also the goods will be monitored directly by the user that is informed about quality and supply chain of the products sold by the Cargo Tram and Cargo Retail that are both part of a travelling market. Evaluation and Reviews are verified and made public.

The Cargo-Tram is provided of a ‘Stock Exchange List’ that can be consulted online and offline on the Tram vehicle and on the Dock/storage units. This service concept makes public the real satisfaction and quality of the delivery service and of the purchased goods.

The Pole B ‘Cargo-Retail / Vital strategies rooted inside territories’ assumes the following phases:

- Monitoring: By the design of a mobile application the user can localize the Cargo-Retail, checking its path, visualize the estimated time of arrival to the next stop and where it is. With the connection to the system ‘New Domestic Appliance / Solidarity Colony’ (Polo B / place) ‘domestic sharing _ The Library of Things’ the user can request/book as group of users a specific neighbourhood sale.

- Choice: Inside the same concept mobile application is available a virtual showcase where all the available goods are shown provided of all the related
information. By his personal profile the user can access to a special selection of goods, see all the ones available and can create a list of his favourite products. These products can be purchased by using the Cargo-Retail or can request a delivery on the storage units provided by the Cargo- tram or can ask for a neighbourhood delivery by the Cargo-Bike.

This formula, connected to the System ‘New Domestic Appliance / Solidarity Colony’ (Polo A / object) ‘domestic sharing _ Biorhythm of purchases’ can increase/preserve local manufacturing small series of products because it can ensure not only the purchase but also a distribution network that helps the delivery and pick up.

Figure 11: System ‘New Way for a Sustainable Growth’ for the scenario |E| ‘Electric goods mobility’ _ Pole A2 ‘Cargo-Tram / Connecting actions of effective change’ _ Diagram : concept main phases.
5. The macro-system |C|A|S|E| : designing a system needs to be systemic and complex.

In the system setting it is necessary to operate with systemic and therefore process logics in order to guarantee vitality in maintaining quality (‘manifest of shared values’ as a profound sense of working for economic growth that is an improvement in the quality of life and in compliance with logics of environmental sustainability) and actions (‘rules of the game’ or ways of operating respectfully and enabling) in the design intervention of products and services whose role is to be an activator node of good relational practices so that the technological innovation they bring can emerge as fertile for further creative processes of change of reality.

The system in mimesis with living organisms is endowed with further self-regulation processes aimed at achieving macro-values and economic growth, aware that the value of goods must guarantee the prosperity of civilization, or through the material culture of which they are brought, to be a vehicle of democracy and aggregation for the new polis.

The material culture in turn operates with principles of complexity, and therefore logical promoters that apparently can be excluded (the requests of the user / consumer, those of the B2B and B2C Transport, those of the B2B and B2C logistics) but which if put in dialogue or if designed as a single system, on the contrary, they are interrelated and from the experience of use they articulate a real coexistence and growth.

In the macro-system |C|A|S|E| we have declined the complexities through experiential practices aimed at a continuous reflection on that triad me-we-them which we cannot as a human condition regardless of as it simultaneously needs a strengthening of the peculiarities of the individual, the recognition of belonging to a group of peers, and of the leakage as an opening to the differences of what is other. The community dimension as the competence to think about oneself in all three possibilities.
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Activist Activated: Efficacies of AR Political Poster Design

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Abstract | The social awareness poster is an artifact (or an artful-fact) of a singular cultural and political moment. These art objects become the graphic legacies of human history. In retrospect, they are visual souvenirs, functioning to highlight the zeitgeists, passions, and hopes of past generations. These objects of persuasion evolve alongside technological advances just as new methods of digital storytelling shape the formal qualities of communication design. As the politically fraught present endures calcifying party binaries and civic apathy, is there an opportunity for social awareness posters to activate a viewer? This paper investigates augmented reality (AR) as a mechanism for re-engagement. The magic and delight of an augmented poster can inspire both physical and intellectual re-engagement, combating “compassion fade,” or the tendency for societal concern to decrease in the face of inundating depictions of tragedy. With AR posters, the space of activation expands beyond 2.5 seconds of 1 static spectatorship, into an inclusive and performative experience in which viewers are invited to participate. A viewer is asked to activate, engage, play with, and share the message. This whimsy invites delight, allowing messages to slip past erected barriers of pessimism and apathy.

Redefining the bounds of activist poster design is particularly necessary in the current political climate. Engaging an apathetic populace requires a venture into those spaces contemporary civilians occupy. More than just brick and mortar, these spaces are digital, liminal. As screens interface and mediate our identities, becoming so called third “eyes,” so too should contemporary political posters exist: between the real and the projected—the phantasmagoric.

This is where the most effective engagement can occur, high in potential for the activist designer: the AR-augmented political posters occupy a digital and physical ecology. During the 2011 Egyptian revolution, for example, Twitter hashtags were used as both graffiti—spray painted on the walls of the city-in-revolt, a physical record in Cairo—and as portals to online forums (Twitter, Facebook), which then called for action in the streets (a positive feedback loop) of gathering activists to campaign and spread ideas on foot (their hashtags literally
meant “tweet the streets”). This was a culturally and time-specific development of new practices in activist communication which combined new media (social media) with the classic repertoire of street level agitation. Just because Twitter or Facebook or cellphones were in everyone’s pockets is not why Egyptians used them, however; but rather, these tools are a reflection of the specific culture of these new political movements (artefacts of a 21st century corporate phenomenology) and of their “popular” character and majoritarian ambitions.

For sustained political engagement and healthy discourse, a combination of physical-digital tactics seems most effective. Political posters that activate a viewer with AR connect the digital to the body, through the use of an augmented eye. Interaction becomes the key, shifting viewers out of dogmatic and stymied positionings. This paper will look at commercial AR campaigns as well as international physical-digital political activism.

**KEYWORDS | AR, POLITICAL DESIGN, ACTIVISM, POSTER DESIGN, DIGITAL AND PHYSICAL ECOLOGIES**

1. Introduction

The social awareness poster is an artifact (or an artful-fact) of a singular cultural and political moment. These art objects become the graphic legacies of human history. In retrospect, they are visual souvenirs, functioning to highlight the zeitgeists, passions, and hopes of past generations.

As a political artefact, the social awareness poster is an art form that persuades. The infamous 1977 Milton Glaser “I <3 NY” poster, for example, was created to increase tourism for the state of New York.¹ The simple design is a monotype rebus featuring a red heart symbol, all locked up in a gridded square: “I (heart) NY.” Now in the Museum of Modern Art’s permanent collection, the poster did so well for the New York State Department of Economic Development that New York City adopted it as it’s branding. Years later, in 2001, Glaser reworked the original design. The designer added a small, charred blemish to the bottom left corner of the heart and new text (“MORE THAN EVER”) below the original rebus. “This was my reaction to the events of September 11, 2001,” describes Glaser. “The only subtlety is the wound, which is located on the lower "west side" of the heart. The shaded portion represented the very area in lower Manhattan where the once proud World Trade Center Twin Towers stood until a pair of hijacked passenger jets slammed into them. Showing a wounded heart is important. To attain healing, the first thing one must do is to acknowledge that there is pain.”² Glaser’s original design may be one of the most well-known designs in the United States, as well as one of the most plagiarized, as you’d be hard-pressed to walk through Times Square and not see the design printed on t-shirts, tote bags, and souvenir mugs.³⁴ The power of this updated piece, then, is in its homage to its 1977 self. The 2001 design asks a viewer to participate in remembering the narrative of a
collective past: to recall what the heart in the 1977 design looked like, unblemished. Using symbolic powers of graphic metonymy, Glaser also persuasively reminds viewers what New York City looked like, pre-September 11th.

This poster is both an artful-fact of collective trauma as well as a rallying cry for solidarity in the face of terrorism. It’s effectiveness relies on a kind of interactivity. Although the viewer is prompted to engage sans high-tech interface, the efficacy of Glaser’s design prompts the question of how new technologies could augment the medium of political poster design. This article outlines the genre’s formal qualities as well as surveys the history of iconic designs. Methodologically, bringing phenomenological theory to bear on the history of street art and poster design will provide a compelling lense through which the design of protest posters can be examined. Finally, this article will examine the landscape of experiential design and digital ecologies (UX and IU) and their application to the poster design in the 21st century, unpacking how new developments in interactive technologies augment the power of the social-political poster.

The political poster is a powerful means of fostering interaction and engagement. Combating civic apathy is important for democracy to function; the social awareness poster can energize citizens to participate in democratic life. As the politically fraught present endures in the United States, with calcifying party binaries and civic apathy, the political-poster-as-art-object has the opportunity to upgrade its tactics of persuasion, maximizing those magical moments of interactivity with new and interactive technologies.

2. Historic Review

Socio-political poster design has always held a mirror up to history. Back in 1972, Andy Warhol was commissioned to create a poster for Democratic presidential candidate, George McGovern. What Warhol actually made didn’t depict McGovern at all. Instead, the “Vote McGovern” poster showed the sickly, snake-green skinned, diabolically orange-eyed incumbent candidate Richard Nixon. Just like in Warhol’s *Marilyn Monroe* or *Mao* silkscreens, Warhol sourced a popular, media-approved portrait of Nixon to use as his base. Warhol’s color alterations, however, completely transform the visage into a disturbing commentary on Nixon’s unsavory character. Visually confronted by the prospect of the alternative, one could only be compelled to do what the poster insisted—“Vote McGovern.”

Design Director and founder of Thirst, Rick Valicenti, writes in Graphis’ *2020 Poster Annual*, “throughout time, posters stand as enduring reflections of the moment they were designed.” Despite predictions that printed materials would perish in the digital age, the printed political poster has not disappeared. Elizabeth Resnick, curator of such comprehensive poster exhibitions as *Art of the Poster* (1999), *The Graphic Imperative: International Posters of Peace, Social Justice and The Environment* (2005), and *Graphic Advocacy: International Posters for the Digital Age: 2001–2012* (2012), states that “the
poster in all its forms has persisted as a vehicle for the public dissemination of ideas, information and opinion.”

From the 2008 presidential campaign of Barack Obama to the Women’s March of 2017, printed social awareness posters have been actively used. One such design, the 2008 “HOPE” poster by designer and street artist Shephard Fairey, is as emblematic as Warhol’s Vote McGovern. The piece, which features a highly stylized version of presidential candidate Barack Obama’s upward-turned face is rendered in three distinct and high chroma colors on a light stone-colored foundation: light blue, dark blue, and red. The cool palette of the historically Democratic Left casts its hue on the left side of Obama’s face while the right side’s vibrant red is of the Republican Right. That said, Fairey does a clever job extending the colors of the polarized parties into the opposite side of Obama’s visage. Red lines outline the left ear and jawline, for example, as well as help delineate the left brow, eye, nostril, lips and neck. The dark blue does the same work on the right. Through the metaphor of color, there is a sense that the binary between Republican and Democrat is not so divided, and in fact one needs the other in order to define a larger whole.

Referencing the abstraction of certain printmaking processes, Fairey uses a color block in dark blue to key the image. This dark blue contains most of the structural elements of the design and thus serving as a “key” for the placement of the other two colors. In this way, Fairey delineates the man in the portrait as inherently blue, Democratic, but hints at a less polarized future with the inclusivity of red on both sides (and vice versa). This could allude to Obama’s potential to alleviate feelings of political amity and alienation, feelings that had increased since 2004.

Beyond party representation, the use of color plays an even more significant role in this piece. According to the National Portrait Gallery’s exhibit featuring the work, the design “forged an unprecedented and powerful icon for Obama’s historic campaign.” This work symbolizes the first African-American president’s career in the Oval Office, in colors that transcend skin tone. These simple, yet powerful, design choices created a piece that became the rallying cry for what political future could look like.

Aesthetically, the posters of Shephard Fairey do not stray far from such iconic designs as 1924 Russian Constructivist poster Books (Please)! In All Branches of Knowledge by Alexander Rodchenko, or J. Howard Miller’s We Can Do It! from the early 1930s. Both utilize dynamic diagonal lines and intense, yet simple, color palettes. They also rely on a heavy stroke weight to control the movement of a viewer’s eye. If there is a palette for politics, these posters have it: reds, blacks, creams, and blues. In political poster design, an artist relies on symbolism that is abundant in the culture with whom they wish to communicate. For example, Alfred Leete’s WWI image of the British war hero Lord Kitchener wagging his guilt-inducing finger at potential 1914 recruits is reused by both Dmitry Moor and James Montgomery Flagg in a USSR propaganda piece and the infamous “Uncle Sam Wants You!” work, respectively. These posters, in turn, do not look so different from the 19th century Parisian lithographic and illustrative advertisements by Henri de Toulouse-Lautrec, Jules
Chéret, Alphonse Mucha, etc; work that gave birth to the modern poster. Through these examples, it is easy to track how symbolic visual language bold typography has persisted through the ages of political poster design. The visual legacy of the printed poster is long and rich. There is little doubt that the medium, as Elizabeth Resnik predicted, will persist.

3. Phenomenological Artefacts

Bernard Canniffe, Chair of Graphic Design at Iowa State University, describes how “every day we are reminded that politicians are either incapable or unwilling to meet...global challenges,” and that “the design profession and design education must work together to address and resolve this imbalance or else we are designing ourselves into an uncertain and fragile future.” “Design conformity and the superficiality of design is as strong today as they were in 1971. We have to stand up for what we believe in, and protest what we know to be wrong.”

To understand how this works, it is helpful to turn to phenomenology as a theory of how we engage with our visual environment. The political poster acts as a social responder, engaging with and from a specific moment in time. Poster and propaganda design are the artefacts of a corporate phenomenology, the products of a self-revealing reality. Martin Heidegger describes Phenomenology as “the process of letting things manifest themselves.” Unpacking the term, Heidegger emphasizes an inner relationship between the root “phenomenon” and “logos,” where “phenomenon” means a “kind of showing” and “Logos” means a “letting be seen.” This theory enables people to see clearly something that is right before their eyes but obscured; things that are so taken for granted that they are muted by abstract observation. The first aim of phenomenology is to reawaken a sense of wonder about one’s environment. Shepherd Fairy describes the goal of his work as attempting “to stimulate curiosity and bring people to question both the sticker and their relationship with their surroundings.”

The political poster functions within this space in two senses. First, the power of the medium’s instant, visual language can provoke a certain type of looking. According to Steven Heller, former art director of the New York Times and author of Design Literacy and Art Against War, the value of a poster is that it provides “the opportunity to see things more iconically.” This is the rapid digestion of messages, of form and color and type, that activate the eye and revitalize the viewer’s perception and attention to detail.

In the second sense, the very physical location, installation site, or material application of the poster motivates a “letting be seen” experience within the viewer. The political poster can stimulate curiosity and bring people to question both the print and the relationship the artwork has with its surroundings. This then prompts a viewer to also begin to “let be seen” the environment and ecology of images and messages they, themselves inhabit.

So, to use Fairey’s “HOPE” poster as an example of the phenomenology of engaging with the political poster, the use of color, referencing both mainstream political parties, discloses not
only the possibility of a political candidate who might overcome both political and racial divisions but the strong desire for such a candidate. The very concrete placement of these posters, on a street level, discloses that one participates in a shared desire, energizing and encouraging political participation in a public and shared space. To better understand this context, in the next section we turn to the formal genre of street art.

4. Street Art

Shepherd Fairey has been "manufacturing quality dissent since 1989." The abstracted and vector-simplified pieces, such as Andre the Giant or the OBEY type lockup, are designed and installed on the streets in order to "make you look and question." It is no coincidence that the venn diagram of social advocacy designers overlaps with that of street artists. Political activism has always been a kind of disruption: the moment that formal architectures or sanctioned messages are ruptured, fractured, silenced, or remixed with the use of rebellious posters, stickers, signage, and graffiti. Street artists like Banksy, Shepherd Fairey, Hanksy, and Grapus create a dialogue between political structures and the voice of the individual.

5. Experiential Design for Engagement

Increasingly, Americans possess feelings of cultural and political polarization between strict party lines. According to recent socio-political scholarship, this polarization has led to mutual feelings of alienation and enmity. Political gridlock has been present for three close elections in the United States: 2000, 2004 and 2016. Coinciding with toxic partisanship is also an over-saturation of visual imagery. According to Eye on Design op-ed writer Lilly Smith, US citizens are today "bombarded by political pundits, email blasts, polls and pollsters, and targeted TV and online ads," She goes on to argue that “distilling what each candidate’s policies and motives are so we can confidently check that box come November, can be difficult if not downright confusing.”

"Today, Twitter has more than three hundred million users, and two out of three Americans own smartphones,” wrote Jill Lepore in a recent article in The New Yorker. The New Yorker also reported that TikTok, the popular short-video app where users repurpose reality into ironic, bite-size content, has over 500 million users. So, in the age of social media instant-streams, how does the poster exist in a world where we look down at a screen for information instead of up?

Experiential design, specifically new participatory technologies such as augmented reality (AR), can be a mechanism for re-engaging the apathetic, the uninterested, or the burned-out. Augmented Reality is the increasingly popular technological technique of viewing the world through a device (like an iPhone camera, or the Microsoft HoloLens), which overlays additional, digital information, images, text, etc. on top of the “real” world view. Additional examples come in the form of Snapchat filters, TikTok meme filters, or the addictive VR scavenger hunt game, Pokémon Go! All of these are augmented reality. Interactive posters,
paradigmatically ones that utilize AR, could shake apathy and politicization within our technological and political milieu of the 21st century.

There is an opportunity, with the affordances of new technology, to re-engage with the needs and desires of people who are today over-saturated with visual imagery. Design must not just get someone’s attention, but also maintain it long enough for the message to sink in. With the digital and physical ecology of an augmented yet physical poster, a user’s phone habits are exploited to make information retrieval a less isolated, more public and participatory endeavor (in the same way that Pokémon Go transformed phone games into a massive, participatory exercise). The magic and delight of augmented posters can inspire both physical and intellectual agency, combating “compassion fade,” or the tendency for societal concern to decrease in the face of depictions of tragedy.\textsuperscript{xvi} Compassion fade is a documented issue, initially published in the Journal of Judgment and Decision Making, by Ezra M. Markowitz in 2013. Compassion fade occurs when: “compassion shown towards victims often decreases as the number of individuals in need of aid increases, identifiability of the victims decreases, and the proportion of victims helped shrinks. Such “compassion fade” may hamper individual-level and collective responses to pressing large-scale crises.” These findings suggest that compassion fade may challenge our collective ability and willingness to confront the major environmental problems we face, including things such as political corruption. Instead, what we do is moderate—thinking, well, I am really commitment to the cause, I liked all my friend’s articles they shared about impeachment, etc.—this only further indicates, though, that compassion fade may present a significant psychological barrier to building broad public support for addressing these problems.

With AR posters, however, the space of activation expands beyond 2.5 seconds of static spectatorship to an inclusive and performative experience, in which viewers are invited to participate. Messages can thus slip past barriers of pessimism and apathy, shifting a person out of stymied positions.

The lens of the camera is our third eye, through which we immortalize our vacations, our puppies, our outfits of the day, our selfies. As Sontag writes in \textit{On Photography}, “the photographic enterprise [is] the very creation of a duplicate world, of a reality in the second degree, narrower but more dramatic than the one perceived by natural vision.”\textsuperscript{xvii} When we use both ours and our third eye we enter the space of augmented surreality, and I propose that this space is rife with wonder, and ripe for activism.

AR works so well because humans have acclimated to viewing the “real” through the “mediated” lens of a camera and taking it as truth. Basically, since Niepce and Talbot and Daguerre invented photography, people believed what the lens portrayed.

Our eyes connect to the lens’ eye, but without losing the body in pure spectatorship because we are forced to compare the discrepancy in the multiple visions. AR offers, then, not only offers the opportunity for play and whimsy, physical interactions and delights that engage
and erode the barriers of “compassion-faded” pessimism and apathy, but also asks us to look critically, to take note, to stay in the experience another second longer.

Interactive posters, paradigmatically ones that utilize AR, could shake apathy and politicization within our technological and political milieu of the 21st century.

6. Digital and Physical Ecologies

This is where the most effective engagement can occur, high in potential for the activist designer: the AR-augmented political posters occupy a digital and physical ecology.

A great example of this is captured in Paolo Gerbaudo’s recent book *Tweets and the streets: Social media and contemporary activism*, wherein he writes about the Egyptian protests of 2011. During the revolution, Twitter hashtags were used as both graffiti—spray painted on the walls of the city-in-revolt, a physical record in Cairo—and as portals to online forums (Twitter, Facebook), which then called for action in the streets (a positive feedback loop) of gathering activists to campaign and spread ideas on foot (their hashtags literally meant “tweet the streets”). This was a culturally and time-specific development of new practices in activist communication which combined new media (social media) with the classic repertoire of street level agitation. Gerbaudo also argues that this shift away from networking, the function hashtags have typically had, to one of “aggregation,” specifically political agitation, is not simply a consequence of new technical tools. Just because Twitter or Facebook or cellphones were in everyone’s pockets is not why Egyptians used them, but rather because these tools are a reflection of the specific culture of these new political movements (artefacts of a 21st century corporate phenomenology) and of their “popular” character and majoritarian ambitions.

It wasn’t just digital, it wasn’t just printed, this was a new choreography of the phantasmagoric and the real.

This 2011 graffiti from Cairo is incomplete, then. As is, it is a pun on Gil Scott-Heron’s famous song-title ‘The Revolution Will Not be Televised,’ with the last verse concluding ‘it will be live.’ What the sentiment of this graffiti condemns is exclusively online forms of engagement that are “often derided as insincere, low-cost, or trivial,” aka slacktivism. In Facebook nomenclature: “Liking” the revolution.

Augmented Reality, on the other hand remains grounded in a tradition of print, it “reads” and depends upon printed material, but requires engagement throughout. The above should actually say: “the revolution will be interactive, all media, and it will consume us.”

Another great example is street artist Escif, a native of Valencia, Spain, who has worked for over two decades to execute graffiti interventions, and recently deployed an AR interventions at the last year with this Kiki Smith sculpture. He says, “I like the way that augmented reality gives the chance to add some new shapes to reality, as graffiti does,
without any authorization needed,” he explains. “Although technology can be a big limitation for expression, it also gives us some new tools for freedom.”

While AR is a trendy technology with which to engage, right now, it is already emerging in numerous industries, including healthcare, education, advertising, navigation, and so many more. And, of course, it will continue to do so as it becomes more accessible. In recent years, AR has changed from a hobby for the tech-savvy into big business. And as the trend with almost all technology, democratization to the layman isn’t far off. At that point, it will fall into the hands of revolutionaries. After all, activist poster design and street art have long been a way to interrupt our surroundings with the unexpected.

7. Applications

Advertising has made sure to capitalize on the connection between AR poster design and audience activation. Facebook, for example, has incorporated AR technology into its set of tools with which brands engage users. According to Adweek, Facebook's approach to AR allows users to “try on” products for the purposes of e-commerce. This capitalizes on a growing interest with AR within the marketing landscape. According to eMarketer forecasts, 68.7 million people will use AR at least once a month in 2019, and that number could grow to 77.7 million by 2020.

One aggressively strategic example of this was implemented by Burger King in 2019. Capitalizing on pre-existing ad campaigns from its main competition, the Burger King app could be pointed at a McDonald's advert to "burn" it, revealing a free Whopper voucher underneath. The feature became a viral sensation, recently winning a Cannes Lion.

The London-based graphic design studio, Omse, also used AR in a 2020 poster exhibition to promote the design and release of its newly minted typeface, Gattica. Called Agenda 2020, the exhibit explored “the graphic possibilities enabled by emerging technology—from variable fonts to augmented reality,” and showcased augmented poster designs filled with typography. The explorations of expanded space and time asked viewers to question the future of static design elements, such as letterforms. In a move not too dissimilar from Facebooks AR marketing, Omse used AR to allow attendees to see their new typeface design alive and out in the world, like a living type specimen book. Taking a more speculative approach, another pop-up poster exhibit called Walkie Talkie in Vienna, also leveraged AR to call attention to forms of communication in liminal spaces. The exhibit housed AR poster designs that prompted a gallery-goer to ask how AR fostered a new medium of communication. What these exhibition examples have in common is how AR makes it possible to immerse an audience in a different world, one in which the laws of physics can be turned upside down. These strange new spaces prompt the question: what are the opportunities and challenges for AR in storytelling, art production, and communication?
A final example of contemporary applications, one that shifts the most dramatically away from the realm of marketing, placing AR poster design within the space of civic activation is the collaborative and multi-platform design project called “Ongoing Matter (2019–2020) by Anne H. Berry and Sarah Edmands Martin. A traveling, multi-platform collection of new poster designs, the AR poster exhibit activates static posters in order to mobilize political engagement with the Report On The Investigation Into Russian Interference In The 2016 Presidential Election, or as it is more colloquially known, The Mueller Report. The goal of the work is, ultimately, to make The Mueller Report more accessible to a wider audience, and subsequently facilitate increased engagement with its findings. Consisting of a series of between twenty and thirty posters, the designs illuminate the major threats to democracy as cited in The Mueller Report. The collection is currently traveling around the United States, accompanying a digital platform showcasing the artwork.

8. Conclusion

Inheriting the spirit of activist street art, AR poster designs re-engage with the needs and desires of a culture over saturated with visual imagery. A combination of physical-digital tactics, like in AR, could be most effective for sustained political engagement and that healthy discourse.

These objects of persuasion evolve alongside technological advances to shape the formal qualities of communication design. As the politically fraught present endures calcifying party binaries and civic apathy, is there an opportunity for social awareness posters to activate a viewer? The magic and delight of an augmented poster can inspire both physical and intellectual re-engagement, combating “compassion fade.” A viewer is asked to activate, engage, play with, and share the message. This whimsy invites delight, allowing messages to slip past erected barriers of pessimism and apathy.

Redefining the bounds of activist poster design is particularly necessary in the current political climate. As discussed via commercial AR campaigns as well as pieces of physical-digital political activism, the AR poster has the opportunity to engage an apathetic populace specifically because its format requires a venture into those spaces contemporary civilians occupy. For sustained political engagement and healthy discourse, a combination of physical-digital tactics seems most effective. Political posters that activate a viewer with AR connect the digital to the body, through the use of an augmented eye. Interaction becomes the key, shifting viewers out of dogmatic and stymied positionings and into a more wondrous space.
References


### About the Authors:

**Author 1** add an author bio that describes research interests and main achievements in a maximum of 40 words. [LEAVE BLANK UNTIL FINAL ACCEPTANCE] [DCs Author Bio and Acknowledgements]

**Author 2** add an author bio that describes research interests and main achievements in a maximum of 40 words. [LEAVE BLANK UNTIL FINAL ACCEPTANCE]

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Activist Activated: Efficacies of AR Political Poster Design

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Art, Design, and Mathematics: Software programming as artifice in the creative process

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Abstract | This article seeks to address the creative qualities of programming in an artistic context. When questioning the limitations of graphical interfaces, we can reflect on the contribution of Programming as a resource to go deeper into a creative process in the context of digital media, robotics, interactivity, generativity and other possibilities. A exploratory research study was conducted through interviews with laboratory coordinators from educational institutions in Rio de Janeiro, who have been exploring the possibilities between Art and Technology for at least a decade. Among the main findings that mark the creative process are experimentation and multidisciplinarity. Distaste for Mathematics appears as the main barrier to the insertion of Programming in an artistic context.

KEYWORDS | MEDIA ART, DIGITAL ART, DESIGN, ART, PROGRAMMING
1. Introduction

1.1 Creative Coding: Art and Technique

A fundamental part in the transformation of an increasingly technological society (Figure 1), Programming allows describing and executing tasks on computers, its use is widespread for functional and deterministic purposes.

![Figure 1. The three modern computing eras (source: Krumm, 2010) illustrates how computers are becoming smaller and more present in our lives.](image)

The use of Programming in an artistic context proposes another purpose. Creative Coding “is not a tool; it is a new way of expressing yourself.” (Maeda, 2004, p. 113), in the work that possibly coined the term, in the book “Creative Code”. By placing artistic expression at the center of Creative Coding, Maeda distinguishes it from traditional programming.

By writing codes, enabling the creation of one’s own tools, it is possible to expand and democratize the design practice, “Conferring (re)designability to technology expands Design. It brings forth a culture that is increasingly understood as co-constitutive and driven by design practice” (Krippendorff, 2000, p.90).

Since the late 1960s, artists and scientists have sought to break the creative limits that emerged with the arrival of computers. According to Oakim (2018), the first visual experiments were generated through a computer by mathematician Frieder Nake, arousing curiosity in the artistic and academic community.

The exploratory proposal of this article analyzes how Programming fits into the creative process and what challenges are encountered in the learning process. Four researchers were interviewed in search of the creative qualities found in the dichotomy between art and technology, concepts that were not always distant from each other:

“We know, for example, that the Greek word tėchnē, from which technology derives, refers to any and all productive practices and even included artistic production. The Greeks made no distinctions of principle between art and technique, and this assumption went through much of the history of Western culture, until at least the Renaissance (Dufrenne, 1980, p. 165). For a man like Leonardo da Vinci, painting a canvas, studying human anatomy or Euclidean geometry and designing the technical scheme of a machine constituted a single intellectual activity” (Machado, 2001, p.24)
1.2 Interfaces and hidden codes

With the popularization of graphical interfaces in the 1980s, artists moved away from coding, but with the emergence of open-source culture, the community created its own tools that facilitate the learning of coding in an artistic context, such as Processing\(^1\), enabling creative coders to go beyond the limitations of closed source software and its interfaces.

When observing the transformations caused by computers in the practice of Design, Krippendorff (2000) analyzes the emergence of these graphical interfaces:

“Personal computers led to the following paradigm: interfaces. Similarities to languages, interactivity, internalized experiences and the possibility of self-teaching made the interfaces not explainable in psychological, ergonomic and semiotic terms, making the language of functionalism, consumer preferences and aesthetic appeals obsolete. Interfaces are processes, they decomposed the artifacts into interactive sequences.” (Krippendorff, 2000, p.89)

The techniques used in Creative Coding require different levels of knowledge, when relating to Programming, each problem becomes a possibility to broaden the understanding of how the software (read Black Box) works. Flusser (2011) analyzes the Black Box phenomenon in the context of the camera, here it can be understood as any element whose functioning is obscure, as such the interfaces:

“Once acquired, the camera will turn out to be a curious toy. Although it rests on complex scientific theories and sophisticated techniques, it is very easy to manipulate. The device proposes a structurally complex game, but functionally simple. A game that is the opposite to chess, which is structurally simple, but functionally complex: it is easy to learn its rules, but difficult to play well. Anyone who has the “latest model” camera can shoot “well” without knowing what is going on inside the camera. Black box.” (Flusser, 2011, p.78)

Being in front of an image editing software distributed by the major software manufacturers, despite allowing a varied range of results, does not contribute to the understanding of how the technique used in the software can be remodeled to enable a new creative bias, these software solutions are made available “closed”, the codes are not accessible, protected by the interests of intellectual property.

The work of Gilbert Simondon was also considered, a French philosopher who developed a system of thinking about invention and technical objects. Simondon “does not only aim at the technical dimension of human life, it defines life within the technical dimension” (Camelozi, 2015, p. 446). If we connect the technological obscurity denounced by Flusser

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and his ability to question the automation of consumption of these devices (interfaces), we find in Simondon’s work a way to decompose technical objects into layers:

1. External layer: appearance, how the object manifests itself socially.
2. Intermediate layer: utilization, compatibility between the object, the medium and the operator.
3. Internal layer: functional core, intrinsic compatibility that the object is capable of producing, making natural resources (energy) compatible with the objective.

Therefore, when questioning closed source tools and their interfaces, we can reflect on the contribution of Programming as a resource to go deeper into the creative process, in the context of digital media, robotics, interactivity, generativity and other possibilities.

2. Method

An exploratory research was conducted through interviews with laboratory coordinators from educational institutions in Rio de Janeiro, who have been exploring the possibilities between Art and Technology for at least a decade. The interviews were conducted through a semi-structured script containing 17 questions, oral recording procedures were adopted and later transcribed. Discourse analysis (Vergara, 2010) was used to present the different views of the interviewees.

The four interviewees (Table 1) authorized their nominations, they can be classified as qualified informants according to their academic trajectory, representativeness in the national and international scene, and historical contribution in Art and Technology. The beginning of Computer Graphics and Digital Art in Brazil is intertwined with the heterogeneous trajectory of these researchers.

<table>
<thead>
<tr>
<th>Name</th>
<th>Academic Title</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>João Bonelli</td>
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</tr>
<tr>
<td>Carlos Nóbrega</td>
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</tr>
<tr>
<td>Rejane Spitz</td>
<td>Postdoc in Electronic Art at the University of California</td>
<td>LAE: Laboratory of Electronic Art</td>
</tr>
<tr>
<td>Luiz Velho</td>
<td>PhD in Computer Science from the University of Toronto</td>
<td>VISGRAF: Vision and Graphic Laboratory</td>
</tr>
</tbody>
</table>

Table 1. Interviewees organized by order of interview.

The first three interviewees went through the entire script, offered valuable contributions and indicated the way to investigate Mathematics as a challenge for inserting Programming into the artistic context, an aspect discussed more specifically with the fourth interviewee, Luiz Velho.
3. Interviews

3.1 About the Interviewees

The interviewees’ academic trajectories were represented by a timeline (Figure 2) built from the facts highlighted in the interviews and the academic milestones listed in Lattes Platform (Virtual Resume System).

Figure 2. Timeline of the interviewees’ academic trajectory. Each respondent is represented by the vertical line, points highlight the milestones of their trajectories. The landmarks were grouped by lines that cross the chart on the horizontal axis, identified on the right side of the chart.
Respondents were asked "when was your first contact with Programming?". The answers varied between childhood and the beginning of graduation, where two of the interviewees reported handling punched cards with Fortran language.

### 3.2 Creative process

The following question was asked: "how do you observe the creative process?". For Spitz (2019), creativity is related to the need for survival, “actions that are caused by curiosity”:

“Creative processes are the result of an individual effort caused by curiosity. Anything is a creative process, as long as someone is looking to know, create or build. I think the creative process is being given a lot of value, it is being highly valued. (...) Creativity is caused by the need for survival. You have to be creative to survive, regardless of anything. Survival depends on curiosity that leads to creative processes. We are creative in absolutely everything, in the way of reproducing, feeding, dreaming, swimming and all these were human creations for survival.” (Spitz, 2019)

Bonelli (2019) observes the creative process through experimentation:

“It is the process of doing something, reflecting on what you did, evaluating, and then doing something else based on these reflections, evaluating and doing something and something else (...) It is not planning and having something in the end, as if in the first day of the project you knew exactly where you were going to go, but doing several experiments and seeing your work evolve after each experiment, until you reach the final result. Constantly re-evaluating your results and objectives. We propose seeing the Design process not as a straight line from A to B, but as a spiral, circular shape, where you arrive at the center, which is your goal, through development and experimentation.” (Bonelli, 2019)

Drawing is in the base of Nóbrega's creative process (2019):

“Usually, people consider the best drawing the one that most effectively represents the thing being observed. The problem is: what is representation, what does it mean to represent something more effectively, because of visual similarity or because it brings information about that thing? You can have extremely simple, delicate drawings that differ from classic drawings, and that are extremely powerful in describing the sensations produced by the thing in question. Great masters, for example, sometimes take a line, a dash, and it takes us directly to their time, 500 years ago, 200 years ago, and you will feel as if you have been transported by that image. So, what is the potency of that image? The idea is to use drawing as a tool for discovering and modulating your own identity, at that moment and in that space.” (Nóbrega, 2019)

According to Nóbrega (2019), among the various aspects that imply the creative process, there is “awareness of an altered state” in a validated reality, one of the 3 realities defined by Ascott (2000). Nóbrega (2019) describes validated reality as:
“Consensus reality, which has a number of issues that are consensual, i.e., it exists because there is a belief, like believing I am here talking to you, and if that belief fails, we stop talking. Reality is not something given a priori, if you start thinking about it, a very wide range of possibilities opens up. So for me, this is the matter in the creative process. The difficulty in creativity is just when you limit the speculative and exploratory aspect of the situation. Of course you master certain aspects, it is important, you will not be making contributions in areas you are not deeply experienced. Within this limit, you try to expand as much as possible with variables, which can bring some freshness to that.” (Nóbrega, 2019)

3.3 Programming and creative process

Then the following questions asked "How do interviewees see the role of Programming in the creative process?". Nóbrega (2019) analyzes Programming as Art by itself:

“I believe programming is expanded when it occurs within a certain system; it is connected, and it connects the system with the whole. It becomes participatory, and several projection mechanisms start to act there, I imagine. You are programming, you are creating something that will be alive there. I think you can think of it as a process of invention. Gilbert Simondon says it is only possible to invent something because there is synergy between your mental state and the thing being created, that is, there is a coupling, a kind of resonance. When you think about it, you are there generating that object in a mental process, you test it and take a series of actions that promote the life of that object, even without it physically existing. So I think that this synergy, probably, should happen in programming because even with the little experience I have, what fascinates me the most is the ability to change a variable and have an extremely complex modification in the work. (...) This is inherent to Art, to the creative process, and it is important that in programming it can be incorporated to a certain extent. I think it’s like the ace in the hole, how you handle the stiffness of programming so it opens up and brings life to the system.” (Nóbrega, 2019)

From another perspective, Bonelli (2019) sees Programming as a tool capable of creating other tools:

“It is like a pencil, a hammer or a handsaw. It is something that will help you get a result, reach a certain result, that will empower you. It is a very powerful tool, because you can build a million things with programming, including a handsaw or hammer, or you can program a robot to saw wood.” (Bonelli, 2019)

Spitz (2019) sees Programming as knowledge, a resource that, like any other piece of knowledge, is part of the creative process:

“Any knowledge is a resource for survival. It’s the only thing you carry, and knowledge cannot be shared, information can be shared, data, but knowledge is individual, is indivisible. Knowledge is contained in a given being, what he/she has learned from his/her experience, and from data and information.” (Spitz, 2019)
3.4 Teaching programming in the artistic context

Then, the interviewees were asked "How do you see programming teaching in an artistic context?". Bonelli (2019) points out the differences between teaching traditional programming and teaching programming in an artistic context:

“We realized that in the IT department, teaching is much more based on questions of logic. They already start giving object-oriented programming right from the start. This needs a lot of abstraction from students, so that they can understand what is happening "right away". We adopt the Processing principle, a programming environment for designers, and we start teaching programming through drawings. When learning with Processing, you start by making an ellipse, a square, choosing the fill color, dealing with the coordinates on the screen. You write, you play, you do something, and not only get results very fast, you also work with a language that designers are very fluent with. Shapes and colors every designer understands.” (Bonelli, 2019)

Spitz (2019) notes that there is a willingness to join Design and Programming:

“Teachers who work a little with programming will tell you that now the new designer has to know how to program and so on. It is not what is happening, we have very little notion of programming for someone to think that we will solve the programming problems of the world. It is a programming layer at the base of Design, it is what we are doing today, whether this is going to change or not is another question.” (Spitz, 2019)

Spitz (2019) mentions that in the 1980s there was a movement that believed it was not necessary to know how to program, after all, everything was moving towards becoming friendly, in terms of interfaces that allowed quick learning and fast results. This in fact happened, but she notes that programming is becoming more friendly as well. Spitz (2019) and Nóbrega (2019) consider the arrival of Arduino as a decisive element that promoted transformation in this sense. For Nóbrega (2019), Arduino allowed people “to leave programming focused on image and go to programming focused on physical things”.

Nóbrega (2019) indicates that “there has been a very expressive growth, over the last few years, in terms of opening up to this universe of “hacks”, of a maker culture, that you can do things”. Access “spread via this open source culture”.

3.5 Challenge of teaching programming in the artistic context

When asked about "What are the challenges for teaching Programming in an artistic context?", Bonelli (2019) says:

“The biggest challenge is hate for Mathematics. In our education system, students get to the university filled with rage at their teachers who tortured them. Those teachers lacked motivation, were not compensated properly, were not talented, taught Mathematics based on threats, on the blackboard. When we talk about sine and
cosine, they ask to leave. The first thing we need to do is to deconstruct, because students reach 18 years old with their ideas shaped.” (Bonelli, 2019)

Based on this reflection, there was a need to investigate the relationship between Mathematics, Programming and Art. For this, interview with Velho (2019) was carried out, where he explains the relationship between Mathematics and Programming: “The scientific basis of computing and programming is Mathematics, if you take Mathematics, this idea of algorithm, you take Newton's method, which is a classic in Mathematics, a program, an algorithm of how you are going to do something”. And he points out the importance of multidisciplinary work:

“It is not possible to work only with mathematicians or experts, it needs to be a complete multidisciplinary group. (...) Today, society is going back to the era of Renaissance, because after Renaissance, we started to have specialization, where each one mind their own business and that’s it. But it wasn't like that before. It was a holistic thing. We are going back to the time of Leonardo Da Vinci, who did Art, Science, Engineering etc. The future will be like that, for that people need to change their attitudes. You can't build a multidisciplinary team with people who consider themselves traditional artists and don't want to understand how things are working.” (Velho, 2019)

The importance of collaboration between disciplines is also mentioned by Spitz (2019) in the same question:

“The only way to make things happen is to have subjects in which Informatics, Design and Art students work collaboratively. If universities were not so compartmentalized... We have some subjects given by computing professors, but it is not the same thing. A class has to have students from Informatics, Design and Arts working on collaborative projects, half-half, 50/50, not 49 and 51.” (Spitz, 2019)

In this place of exchange, where subjects gets mixed and need to speak the same language, the need to understand the outlier, in this case, Mathematics, is evident. Velho (2019) talks about the contributions of Mathematics:

“We are at a very special moment in humankind. Mathematics is the engine of innovation, and people still haven't realized that. With the internet and the evolution of media, the third industrial revolution is happening in our society, but it is not mechanical, it is intelligent, it is mathematical intelligence. The three most important things today: biomathematics, artificial intelligence and the media. And Mathematics is behind this.” (Velho, 2019)

When reflecting on the challenges of learning and teaching Mathematics, Velho (2019) says:

“Mathematics is very simple, it has two aspects: essence is the concept, and the operational aspect is the accounts. The accounts can be laborious and sometimes even complicated, but when you know the concept and you are going to do it, it is easy. It is very specialized. But the central idea of Mathematics is simple. (...) People are what makes the difference.” (Velho, 2019)
4. Analysis

A curious finding, but yet inconclusive, is the early contact with programming shared by the interviewees. Even for those with higher artistic inclination, an early contact with computers and programming suggests a familiarization with the necessary techniques to dialogue with emerging technologies and, therefore, a distinguished nature during a professional, artistic and academic trajectory. Today, more and more schools are providing programming for children all over the world. These courses use tools such as Scratch\(^2\) to teach programming logic through the creation of games, interactive stories or parametric drawings. Plans such as UNESCO’s (2019) technology literacy help future generations acquire knowledge to dialogue with technological transformation in a non-passive way.

The perception of a creative process was associated with the practice of each one, whether through drawing, experimentation or multidisciplinarity. Collaboration between disciplines was recognized as a key element for innovation. Based on Simondon’s ideas of invention (2008), Design, as any other discipline, goes as far as Design can go, by collaborating with other disciplines, as a result of an “amplifying dialectics”, it produces “functional surplus-value” (plus-value fonctionnelle): This explains, therefore, why technical inventions have “superabundant functions” (fonctions surabondantes), because it gives an amplifying leap regarding the potential of separate objects.

Choosing between multidisciplinary training, where Programming teaching would be inserted in other courses, versus specialist training, encountered an equalizing proposal: the collaboration between courses mediated by projects, where students from different courses can share and develop their skills.

The main barrier for the insertion of Programming in an artistic context appears to be the hate for mathematics. The feeling that “students accumulate negative experiences in their learning path” (Bonelli, 2019) can be observed in the percentage of students with adequate learning in Mathematics, where there is a "considerable growth over the period of the initial years of elementary school and very low levels in the final years and high school, with stagnation/downward trend in recent years.” (Todos Pela Educação, 2019, p. 24)

According to an evaluation carried out with 600,000 students from 79 countries, the challenge of stimulating the pleasant learning of Mathematics is a worldwide challenge:

“76% of students attained Level 2 or higher in Mathematics. At a minimum, these students can interpret and recognize, without direct instructions, how a (simple) situation can be represented mathematically (e.g. comparing the total distance across two alternative routes, or converting prices into a different currency). However, in 24 countries and economies, more than 50% of students scored below this level of proficiency.” (OECD, 2019, p. 15)

As seen in the interviews, the human element, i.e., teachers and students is yet, another decisive factor in teaching Mathematics. The Profissão Professor report (Todos pela Educação, 2018) carried out a quantitative survey of 2,160 basic education teachers from all over Brazil. Although the decisive factor for choosing a profession is the pleasure of teaching, half of the interviewed teachers answered that they would not indicate the profession to a young person, because of the “devaluation of the teacher, poor remuneration and difficulties in the routine” (Todos pela Educação, 2018, p. 15).

5. Final considerations

While graphical interfaces became more practical and more popular, so did Programming. Languages and tools were developed to facilitate learning and promote artistic expression through code.

Programming was observed as inserted in the creative process so that it solves the technical problems to make the project viable. It is marked by an experimental process, where unexpected discoveries are concatenated in the project.

The hate for Mathematic appears as a barrier to the insertion of Programming in an artistic context, where quantitative research in the Brazilian context has shown that the challenge extends itself to a precarious education system, and the main aspect of concern is the teacher. As a suggestion for other research, it might be interesting to investigate whether the same happens in other countries.

The 4 interviewees already had contact with Computers and Programming before or during the graduation in the areas of Art, Design and Mathematics, suggesting that they were more familiar and ready for the technological transformation along their learning path. It would be worth researching whether the teaching of Creative Code for young people collaborates with positive experiences in learning Mathematics.

References


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Artificial Creativity – Hybridizing the Artificial and the Human

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Abstract | This paper focuses on the creative practices used in the field of design that integrate artificial computerized systems. It refers to the double faceted nature of design as generating both form and function. Following philosopher Luciano Floridi’s analysis of human-technology-nature relationships, this paper points to different typologies of “creativity” that are now possible through the capabilities of technology that take part in the design process. It addresses creative processes grounded in machines that operate autonomously as well as through hybrid processes that combine human and machine operations. Suggesting that new emerging forms of computational creativity in design mark the transition from human to post-human design, this paper argues that the computerization and “scientification” of creativity maintain values of unpredictability, newness, and originality inherent in aesthetic creativity. Yet, it will argue, applying different parameters on creative computerised systems entails social and political values that should be analysed.

KEYWORDS | COMPUTATIONAL CREATIVITY, AUTONOMY, POST HUMAN DESIGN, HYBRIDITY, IN-BETWEENNESS
1. Introduction

Creativity is perceived as one of the central buzzwords of the present era. Contemporary culture is based on rhetoric that presents creativity and innovation (a coupling concept), as preferred values. It is considered a primary condition to cope with states of instability and transience that characterize the current reality. Creativity is strongly connected to neo-liberal concepts that foster the production of an unceasing supply of commodities in order to maximize profits. It is presented as an engine for growth and as a condition for economic resilience and is a leading principle in the branding of countries and institutions, as well as individuals. Nowadays, technological developments are considered the key stimulators of creativity.

Although many definitions for the concept of creativity have been formulated over the years, no consensus has been established in relation to any of them (Robinson, 2008). The divergent definitions are often attributed to different authors and are cited in relation to their specific context. Furthermore, these definitions apply to the various aspects of this term: “Some definitions are formulated in terms of a product, such as an invention or discovery; others, in terms of a process, a kind of person, or a set of conditions” (Torrence, 1971, p. 552). Yet, in spite of the differences in definitions, they all address the concepts of “novelty” (Cropley, 2011).

From the perspective of modern thought, it is possible to stress two main approaches to creativity. The first is grounded in Kant's philosophy, which realizes creativity as embodied in the act of "the genius." According to this concept, creativity is an innate trait that cannot be obtained by learning and therefore it is not a product of rational and structured thought. As such, it cannot undergo processes of methodization or imitation. From the mid-twentieth century, a structured scientific practice to explore creativity has been developed mainly in the fields of psychology and learning (Martiniano, 2016). Since the 1990s, the "scientification" of the creative process has expanded into many other fields and has become a major factor in the natural sciences and other areas of the social sciences: sociology (Elisondo, 2016; Reuter, 2015; Reimeris, 2016); psychology (Mehta and Dahl, 2019; Kaufman & Sternberg, 2019); economy (Howkins, 2001, 2014) as well as in the fields of art (Ingold, 2010; Kaufman & Paul, 2017; Elliot, 2017) and design (Julier & Moor, 2009; Darbellay, Moody & Lubart, 2017). Consequently, new definitions of creativity have been introduced that conditioned the existence of the creative processes in structured knowledge and discipline. Creativity is thus seen as an acquired and imitative feature that is often associated with problem-solving practices in existing situations rather than the creation of something new (Martiniano, 2016, p. 163). The “scientification” of creativity also communicates a broader trend of imposing research methodologies and practices from engineering and computer science into the life sciences. This was the result of the ability to

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1 The "scientification" of the creative process can be traced back to the 19th century, with the first attempt to explore creativity with scientific tools in Galton's study of the “genius”, as early as 1869. (Eysenck, 1993).
encode them with scientific tools, life-processes, and materials, and to modify them in processes that can be recognized as creative.

This paper will focus on the creative practices used in the field of design that integrate artificial computerized systems. It will refer to the double faceted nature of design as generating both form and function. Following philosopher Luciano Floridi’s analysis of human-technology-nature relationships, this paper will point to different typologies of creativity that are now possible through the capabilities of technology that take part in the design process. It will address creative processes grounded in machines that operate autonomously as well as through hybrid processes that combine human and machine operations. Suggesting that new emerging forms of computational creativity in design mark the transition from human to post-human design, this paper argues that the computerization and “scientification” of creativity maintain values of unpredictability, newness, and originality inherent in aesthetic creativity (Bodem, 1995). Yet, it will argue, applying different parameters on creative computerised systems entails social and political values that should be analysed.

2. Man, machine and creativity

In the new complex techno-human ecology in which designers act today, the clear distinction between humans and machines that has characterized modern Western thought in the past, is becoming increasingly blurred: Computer systems and the logic of code are embedded in the most essential characteristics of human existence, while automated machines are acquiring traits of living systems. Thanks to new developments in the field of computer science as well as in the natural sciences, the new algorithm-based machines are no longer characterized only as computational apparatus of a significant logical nature, but they also take part in areas that were previously considered unique to human beings, especially in the creative field. Therefore, the binary distinction between a thinking human-being who learns and creates, and the executive machine that optimizes and improves human activity through embedded automation systems is being undermined. The matrix of control of humans over machine and the dichotomous division between nature and culture is being replaced, as claimed by Bruno Latour in his Acor-Network Theory (ANT) (Latour, 1996), by the perception that human beings and ‘things’ are not necessarily autonomous entities distinct from each other.

Undermining human autonomy while recognizing the ability of non-human entities to generate creative processes was manifested in various contexts during the twentieth century. For example, Freud rejected the concept of human autonomy in light of his claim that the subject is controlled by the ego, the id and the super-ego (Freud, 1991). Piaget argued that creativity is a product of an adaptive process in which mental structures interact with the environment (Piaget, 1972), while Charles Pearce showed how the concept of reasoning as a compulsory condition for mental processes, can take place in machines as

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2 These machine’s creativity is implemented both with respect to information – through the use of algorithms, and on material phenomena – through identification of the material’s ‘code’ and the ability to modify it.
well (Pierce, v2, p. 56). However, acknowledgment of the machine's creative capabilities is a result of the developments in computer science, especially those relating to computerized learning capabilities and drawing conclusions through artificial intelligence applications.

Figure 1. Patrick Tresset, Human Study #1 5RNP, Trace Exhibition, 2018, New Media Gallery, New Westminster, Canada. Photo: NMG

Autonomous robots challenging the most epitomic representations of artistic creativity – drawing and painting, have been developed as part of the exploration of computer creative capabilities: Artist robots have included Aaron, created by Harold Cohen back in the 1980s, The Painting Fool, developed by Simon Colton (2001), Paul conceived by Patrick Tresset (2011), and the AiDA robotic painter, devised in collaboration with Oxford University and introduced to the public in 2019. Additional applications were developed in various creative fields, such as systems in the field of music, capable of taking part in real-time jazz improvisations along with human musicians; an algorithm that wrote a musical piece similar to Bach’s, a sequel to Harry Potter, and poems written autonomously by artificial intelligence programs. In the various fields of design, many generative platforms have been created using AI such as the WIX web design, Tailor Brands for building brands, Spacemaker

3 See: The BachBot Challenge https://bachbot.com/#/?_k=ta71ou Retrieved February 9, 2020
4 “Harry Potter and the Portrait of What Looked Like a Large Pile of Ash” https://botnik.org/content/harry-potter.html Retrieved February 9, 2020
for urban planning, Finch for planning floorplans, as well as new emerging GAN (Generative Adversarial Networks) platforms about which, considering their outputs, it is difficult to discern that they were not created by man.

Figure 2. Dragan Ilić, Roboaction(s) A1 K1 Courtesy: Dragan Ilic and GV Art London

The introduction of creative abilities into machines can, on the one hand, lead to dystopian perceptions based on fear of the takeover by computational systems of human creative tasks in a way that will leave no space for human designers. On the other hand, it suggests that creative capabilities in machines can provide an opportunity to redefine creativity in new ways that are possible only through the inclusion of machines. Dragan Ilić’s work, “Roboaction(s)A1 K1”, metaphorically demonstrates these two perceptions regarding the inclusion of machines in creative processes. Using an advanced robot, Ilić creates monumental drawings on canvas while his body is rotating at a speed along a vertical and horizontal axis connected to the robot’s arm. By using an elaborate brain-computer interface (BCI) system he controls the robot with his brain. Although he controls the creative process by manipulating the movement of the robotic arm, the traditional relationship

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5 Demonstrations of creative use of GAN: https://towardsdatascience.com/14-deep-learning-uses-that-blasted-me-away-2019-206a5271d98 Retrieved February 9, 2020
6 http://www.draganilic.org/work/?y=2017 Retrieved February 9, 2020 Retrieved February 9, 2020
between man and the machine as the executing factor is reversed. Here the robot uses man as his paintbrush, and thus leads the creative process. Therefore, it undermines the binary distinction between the thinking, learning and creative human being and the executive machine that optimizes and improves human activity through the automation systems embedded within. Yet, within this human-robot hybrid, man enjoys new possibilities granted to him by the machine. This work offers a new way of thinking about creativity as a human-machine collaborative act.

3. Computational Creativity and the Possibility for Post-Anthropocentric Creativity

Common human discourse on computational creativity systems analyses the ways such systems are capable of performing creatively on a human level or even going beyond it. In addition, it aspires to a better understanding of human creativity and attempts to formulate an algorithmic perspective of creative behaviours in humans. \(^7\) In order to better understand the potential of computational creativity within the design discipline, the contextualization of the changing relationships between man and technology is necessary.

In his article "Technology's in-betweeness," philosopher Luciano Floridi offers a view that challenges the anthropocentric approach to technology. He proposes to classify technologies by three categories of order that describe their relationships with their users (Floridi, 2013). These categories differ from each other in the different relations that they incorporate between the feature of “in-betweeness” that refers to the interacting user, and the concept of “affordance” which refers to the enabling factor of the interaction. The first two categories have lain at the basis of the relationships between man and the world surrounding him throughout human history. First-order technologies are the most basic: They stand between the user and the world of natural phenomena. Although they can be complex in themselves, and sometimes even rely on other technologies, even nonhuman beings can apply them. Second-order technologies are the most common and include technologies used by people, but they always involve other technologies. Third-order technologies, in contrast, are technologies that refer to other technologies as users. They exclude the human subject from the chain of interactions and hence become autonomous. Yet, despite the clear distinctions between the three order technologies, different technologies can be attributed to each of them with regard to the context of their performance.

Following Floridi’s analysis, I would like to propose three different typologies in order to understand the potential of machine’s creativity and to examine the ways these forms of creativity are being applied in the design field. As in Floridi’s model, I will refer to the classification of creative modes as contextual.

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\(^7\) https://en.wikipedia.org/wiki/Computational_creativity Retrieved February 9, 2020
Artificial Creativity – Hybridizing the Artificial and the Human


**man-[machine-word]** - The first typology is based on computerised generative processes that are not necessarily creative in nature. Creativity takes place in the human-machine encounter and cannot exist without it. In this case, the machine contributes to the design of objects that exceed human intuition. The ability of the machine to produce aesthetic forms that go beyond the realms of intuition derives from the complexity of the operations that the machine can perform. The works of Swiss architect Michael Hansmeyer who creates forms generated by an algorithmic code based on a subdivision principle is an example of this kind of contribution. The many iterations performed in the design processes give rise to shapes that the computer can generate that cannot be imagined by humans and cannot be manufactured without computerised tools. Another example is Alisa Andrasek’s project “Abundance”: a robotically extruded microstructure in the form of lightweight lattice, generated by applying Perlin noise through the voxel cloud. Here again, computerised algorithms overcome human limitations: “Since the pattern recognition in such a cloudy noisy structure exceeds human cognition and the designer’s capacity to search, there was a clear need for machine learning assistance for the design process.” Additional algorithms

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were required in order to overcome the high resolution printing process which was based on an adaptive feature, making this printing feasible. Creativity in this context is made possible by technologies that extend the range of possibilities through which phenomena in the techno-natural world can be accessed by creative humans and become objects of design: The creative process is based on human decisions but cannot emerge without partnership with the machine.

**machine- [man-machine]** - The second typology refers to the creative ability of machines using artificial intelligence applications, trained by humans and run according to tasks they are assigned to perform. They operate autonomously without human intervention in ways that can be perceived in human contexts as creative. Most of the platforms used in these contexts are based on neural networks and supervised machine learning. To enable the creative process, objects in various media formats and genres are fed into the computer database. By learning the properties of groups of objects, the system acquires the ability to identify repeating patterns that form the ground of new objects that have had no previous existence in the past.10 Another manifestation of this typology is a creative platform that manages to emulate mechanisms of creativity without being limited to a predefined field of creative action. These platforms are “trained to imitate a set of human designers by observing their design state sequences without inducing problem-specific modelling bias or extra information about the problem.” (Raina, McComb, & Cagan, 2019, p. 1) It can be claimed that this kind of creativity, does not produce anything "truly new and creative" that goes beyond what has been previously structured and familiarized. In Fredric Jameson terms, it can be considered as “pastiche” - an expression of a culture based on the imitation of existing patterns. Yet this kind of computational creativity can generate outputs in intricacy, scale and variety that introduce new possibilities for design.

**machine- [machine]** The third typology is characterised by machine autonomy, independent of human supervision and with no clear definitions of the creative process.11 Such creativity is generated within and between computerized systems, applying logic that does not necessarily resemble human creative processes.12

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10 An example of such a process is the project “The Next Rembrandt”, in which an AI system has autonomously painted a portrait which has never been painted before but resembles Rembrandt’s original paintings with great proximity. https://www.nextrembrandt.com/ Retrieved February 9, 2020

11 A broadly cited example of an autonomous design process is the design of the partition for an Airbus aircraft that offered an efficient and cost-effective solution, perceived by designers as an "out of the box" solution, not resembling human design precedents. See: https://www.autodesk.com/redshift/bionic-design/ Retrieved February 9, 2020

12 There is frequent use of the term “black-box” in relation to the opacity of many of the AI systems whose operations cannot be traced by developers. Recently, different applications have been written in order to follow the system operation’ logics.
The “new generation” of autonomous creative applications capable of creating new objects or behaviours, which can be employed in the field of design, are characterised by mechanisms of emergence, growth and evolution, inspired by biological processes. Unlike supervised deep learning which is applied on modelling of what we know by training on an existing data set, autonomous creative computation is focused on generating solutions for what does not yet exist. The unpredictable nature of this creative modelling arises from the stochasticity embedded in computational operators like mutation, recombination (crossover), and selection, defining some of these computational models. Rather than on a single, continuously refined solution, these models are based on a population of solutions. Therefore, they can afford to try out novel ideas and discover creative solutions which cannot be conceived without the complexity and diversity of the computational processes (Cohen-Or & Zhang, 2016).

Although experiments in creative modelling via evolutionary design have already taken place in architecture and urban planning in the last decades of the twentieth century (Balling, Taber, Brown, & Day, 1999), implementing autonomous systems excluding human involvement is still in its first stages of development. We are at the beginning of a process whereby machines will have to apply proactive autonomous design practices in order to survive and optimize their operations. The massive implementation of IoT systems and autonomous agents, and the need to ensure their resilience and ability to adjust to new evolving conditions will be accomplished to a large extent with algorithms written by algorithms, leaving human agency redundant. Therefore, it stands to reason that future creative design will not only perform with no direct human intervention, but will be the outcome of machines communicating with each other.

3. Creativity, noise, and the concept of “in-betweeness”.

A source of reference to creative and autonomic systems is the concept of autopoiesis (self-creation), which was coined by biologists Maturana and Varela, relating to the question: What is life? They defined living systems as ‘self-producing’ mechanisms which maintain their particular form despite material inflow and outflow, through self-regulation and self-reference (Varela, Maturana, & Uribe, 1974). An autopoietic system, according to this definition, can grow itself out of itself, and can regenerate through self-organizing processes. Sociologist and philosopher Niklas Luhman, in adopting the concept of autopoietic systems for sociology, argued that for a system to maintain its autonomy, it should have the ability to partially overcome external noise. (Luhmann, 2000)

In her book How We Became Posthuman, cultural theorist Katherine Hayles shows how both, cybernetics and information theory, which developed in the 1940s and 1950s, embraced the modern values of creativity, individuation and creation of the new (Hayles, 1999). She indicates that paradoxically, in Shannon Weaver’s theory of information, it is the noise which is perceived as unexpected and random and thus enhances the value of the information (Wiener, 1954). By disrupting the tendency toward homogenization and the
entropy of knowledge, it prevents the condition in which routine information causes the system to atrophy, and to envisage predictable patterns. In cultural contexts, a literary work can be seen as rich in information while clichés are cultural forms with diluted information (Hughes, 2005, pp. 371-72).

In order for information to be effective, as artist and culture researcher Hito Steyerl claims, there is also the need to clean up irrelevant noise. Therefore, creativity is stimulated not only by the existence of the noise, but also by the ways it is decoded. Steyerl makes the analogy between the process of distinguishing noise from information, to social formation as described by philosopher Jacques Rancière: “to distinguish between noise and speech to divide a crowd between citizens and rabble. If someone didn't want to take someone else seriously, or to limit their rights and status, one pretends that their speech is just a noise...” (Steyerl, 2014). Since design is fundamentally social, we should follow Steyerl’s question "What is the political and social algorithm through which noise is cleared from the information," and explore the ways these processes occur in computational design creative processes.

One of the most significant definitions in the field of computational creativity is that of computer scientists Colton and Wiggins, who define this concept as follows:

“The philosophy, science and engineering of computational systems which, by taking on particular responsibilities, exhibit behaviours that unbiased observers would deem to be creative.” (Colton, 2012, p. 21)

Referring to the concept of computational creativity, Colton and Wiggins address the need to analyse this term on a meta level. The notion of responsibility, which they regard as a fundamental characteristic of the creative process, lies notably in the evaluation practices and quantification criteria which are applied to the system’s creative behaviour. This is done in order to empower and refine the system’s autonomous creative abilities through a learning process which can also be optimized. Therefore, while the creative process in its “aesthetic” dimensions is characterized by unique qualitative virtues, within computational creativity, quantitative breadth such as efficiency, speed, level of appropriateness and minimal exploitation of resources as manifestations of optimization, are also becoming part of this process.

In their article, “Data Mining and Machine Learning in Computational Creativity,” Toivonen and Gross explore the potential for a new affinity between autonomous computerized creativity and other factors. They argue that, in order to achieve creative autonomy and originality in systems, it is necessary to attribute both self-determinism and adaptability to them. The system’s creative capabilities rely on its autonomy to evaluate the creative process. In order to avoid repeating patterns and formulas, they propose using data mining and machine learning methods. They argue that the motivation for changing the evaluation criteria of the system comes naturally from outside the system through feedback of its action or through reliance on another creative system which could also be human. Therefore, they argue, creative autonomy is strongly related to social interactions (Toivonen & Gross, 2015).
At this point, referring to machine-to-machine creativity, I would like to return to Floridi’s concept of in-betweeness. Following his assertion that technologies are always in-between, he points out the special new condition of third order technologies: Since those technologies interact with other technologies, “all the in-betweeness becomes internal, no longer ours but technologies” (Floridi, 2013, p. 114). Although, “[s]uch a process of ‘internalisation’ is a source of concern about ICTs ending up controlling human life, these technologies can still generate new externality and therefore still preserved the “technological in-betweeness” (that gives the context to their use). In this way they can create a new space outside the loop”. This is “a space made possible by the loop, that relies on the loop to continue to exist and to flourish, but that is not to be confused with the space inside the loop” (Floridi, 2013, p. 115). Such a space, as he claims, could be cyberspace.” He argues that “out of the loop spaces” are not new in human history, but new technologies have generated immense change in the scale and pace with which the whole of human society is now migrating into them.

The social dimensions of such processes take place, among others, with the integration of feedback systems in which human beings are involved, and therefore become a component in the design process. This has a special significance, for example, when human consciousness, which becomes a new “affordance” in Floridi’s terms, in the context of complex feedback systems, evolves to be the object of optimization through the use of vectors of behavioural control by systems of artificial intelligence which play a role in the design process. These processes are based on new forms of in-betweeness within complex networks operating in the framework of the design practice and may bear many social and political implications. They incorporate human beings and machines, as well as other agents which are relevant for the creative process. Therefore, conducting an autonomous computational design process with no human intervention or intention can be still connected to human activities as a parameter in the design process or through its resulting product.

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13 See for example the way Michael Hansmeir and Alisa Andersek use feedback processes in their designs constructing a model of the relation between abstract geometric properties and the human perception.

14 The use of such feedback systems has also had a strong influence on the cultural and political space, as we have witnessed, for example, in Cambridge Analytica’s involvement in the US election campaign and the UK referendum on Brexit.

15 The use of the term “actants” follows the use of this term as defined by Latour’s Actor Network Theory (ANT).
3. Concluding Thoughts

Bruno Latour proposed to understand technology through the idea of the fold. In technical action, time, space, and types of "actants" are folded together and take part in a process of shaping one another. Technology, he claims, is not simply used by humans but helps to constitute them as they both operate as part of a network. In such a network, the degree of autonomy shifts between the different actants that operate within it. Therefore, human perception, scale, and passion are no longer the first measures of value (Latour, 2002).

As explained, computer-generated creative platforms have been developed to adapt to the characteristics of the information space and to the new possibilities that they present. In addition to imitating human creative models, non-supervised creative platforms, as well as biologically based models (emergence / genetic / evolutionary) have been developed and are being further developed. These mark a transition from the adherence to human intent and conceptual construction, to the unknown, bizarre, mysterious and unpredictable. They enable processes that go beyond human intuition in many facets of design creativity: from the ability to imagine shapes and speculate scenarios, through problem solving, and the ability to connect objects from different ontological realities. They function within complex and information-intensive systems that humans cannot comprehend. With the total departure from the binary separation between man and machine, a new paradigm of human-machine creativity can be explored where the borders between the proactive actant and emerging/evolving automated processes cannot always be distinguished.

In the current state of affairs, creativity has ceased to be considered an exclusive human virtue. Yet, as the ecology in which creativity can take place is constantly changing, the concept of creativity in the new “in-betweeness” and “affordances” provided by the use of computerised networked systems, gains social and political attributes. In this case, the image of the single author who derives its legitimacy from the romantic concept of a "creative genius" is being challenged not only through deconstructionist and post-structuralist theories, giving rise to anonymous, collective collaborative practices, but also through a complex data space hybridized with actants of different forms and origins. Therefore, thinking about computational creativity demands a great deal of awareness of the various platforms and infrastructures that make it possible to implement creative processes within the data scape and to the way they perform: the kind of algorithms in use and to their limits; the types of trained databases being exercised and the politics behind them and the domains in which they operate. In this respect, special attention should be given to the ways parameters such as pertinence, identity, noise and optimization, are generated and to the value systems they embody.
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Artificial Intelligence is a Character? Exploring design scenarios to build interface behaviours.

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Abstract | The paper aims to illustrate the qualitative results of the first phase of the scenario research about voice interfaces, examining whether it is possible to design them as if they were a theatrical or cinematographic character. The research field intersects interaction design with character design, intended as the narrative construction of a character, and theatrical performances. The experimentation takes advantage of theatre workshops that aims to show, and understand, which are the main characteristics of a vocal interface and how to design them according to a performance approach. The paper ends illustrating how design can address actual opportunities and criticalities about emerging technologies, following a relations-based approach.

KEYWORDS | INTERACTION DESIGN, VOICE USER INTERFACES, CHARACTER DESIGN, SCENARIO, THEATRE WORKSHOP
1. Introduction, from voice to personality

In recent years, there has been a widespread diffusion of devices that integrate vocal interfaces closely connected to artificial intelligence. Although these issues were already debated in the scientific community during the early 1990s, only in the last decade this topic experienced greater insight from many disciplines, including interaction design. The renewed attention is linked to the massive diffusion in the daily life of two products-functions: voice assistants (SIRI, Google Assistant, Alexa, Cortana); smart speakers (Amazon Echo, Google Home) that had a surge in sales. The scenario also includes extremely complex products, such as robots, voice assistants on board of cars with different degrees of automation and web pages applications. Therefore, the research field appears to be very broad and even in the scientific literature names of the vocal interfaces are connoted with different nuances. They are defined as Vocal Agent (VA), more often as Vocal Assistant, Conversational Agent (CA), Intelligent Assistant (IA), Virtual Assistant (VA). Robotic scientists, for example, imagined them to help fill the gaps in human social relations to generate friends and companions (Richardson, 2015). If the set that contains all the definitions is called Natural User Interfaces (Dasgupta, 2018), much is being discussed not only on the functions of the interfaces but, above all, on aspects such as: the emotions they should communicate, the characteristic traits of the personality, the ability to stimulate virtuous behaviours. The concept of naturalness is still debated in the scientific community, but the dialogue makes interaction easier because voice interfaces currently allow a great tolerance in the understanding of the input messages, without forcing the user to be strict encode and learn standard messages to be given in a dialogic fashion (Dale, 2016). Moreover, the voice is not only perceived as human-like, but human traits are also associated with the behaviours of the system (Nass, Steuer & Tauber 1994). People tend to infer more a human creator behind the computer, hearing a voice than reading the same text (Schroeder & Epley, 2016). Even if users are perfectly aware of the presence of an artificial intelligence, they believe that voice-human has real needs and desires (Short, 2017), human emotions or traits (Brave & Nass, 2007), feeling even more comfortable when VA asked invasive questions (Yu, Nguyen, Prakkamakul & Salehi, 2019). People create a mental image of the voice, including personal traits, attitudes, background information and even physical characteristics (Cohen, Giangola & Balogh, 2004). Starting from this statement, VAs are usually designed to include emotion appraisal (Castellano et al., 2013), generation and expression capabilities (Tsuuorti et al., 2016), to produce empathy (Lunardo & Bressolles, 2016). Other attributes usually associated with VA are: empathetic (Fung et al., 2016), affective (Oker et al., 2015), emotive (Maldonado & Nass, 2007). All these efforts are made to foster communicative and emotional aspects, but the core concept follows the design of a human-like interface, defining it as emotional intelligence, that is grounded in parameters like: believability (Ranjbortabar & Richards, 2016), the illusion of life (Bates, 1994), collaboration (Cassell, Sullivan, Churchill & Prevost, 2000), trust (Cheepen, 1988), sensitivity (Dibitonto, Leszczynska, Tazzi & Medaglia, 2018), capable of conversing (Clark et al., 2019). However, one of the most debated topics is how to give to VA a recognisable personality to simulate a
Artificial Intelligence is a Character? Exploring design scenarios to build interface behaviours.

real human-like dialogue; many scholars apply the same personality model both to the human and the machine side, because the base construct is to create a match between human personality and the machine one. But, at present, the VA wide spreading generated an unusual loop in which scholars are still analysing commercial VUI to find if there is a clearly designed personality, which categories of user can easily accept, adopt and engage a stable relation with that kind of VUI. While personality is well described by Corr and Matthews (2009) as "the set of habitual behaviours, cognitive and emotional patterns that evolve from biological and environmental factors", then the first split concerns the subdivision between the personality traits theory and the personality types one. Personality trait theory considers characteristics of people as part of a larger continuum and its approach is described into the Big Five theory; personality types theory, instead, describes characteristics of people as discrete categories. Big Five theory (McCrae & John, 1992) specifies the general affective behaviour by the five following traits: Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism. Type theory has its roots in personality scales, such as the Myers-Briggs Type Indicator (1962), which posits 16 personality types deriving from a set of four fundamental dichotomies, for example, extroversion vs introversion. It is worth noting that in the analysed studies, scholars do not use the two approaches as separate, but often mix them by adding other parameters, see for example Heudin (2017), such as mood (Morris, 2012) and emotion (Campos et al., 1994).

2. Analysing and designing personalities of VA

The literature review presented in these first two sections aims to show how interaction design considered the aspects of voice interfaces design, especially the humanization aspects, including users’ inferences. The analysis includes design and psychology references as the research field is multidisciplinary, but broadens the field also considering character design. Garcia, Lopez, and Donis (2018) analysed 3661 online surveys to assess the VA personality; their goal was to evaluate VA and identify people desired VA personality. They found that: attributes most frequently associated with VAs were practical, informed, up-to-date, well-mannered, logical and helpful; the least associated were cheerful, sweet, sentimental and masculine. On the other hand, Ehrenbrink, Osman, and Möller (2017) found the personality profile of testers and their preference for Siri, Google’s Now and Cortana, based on attractiveness and psychological state reactance. The results show how the group of testers who preferred Siri was the largest and matched the average personality profile. The Google Now group was preferred by extravert, the group that preferred Cortana was more neurotic, less agreeable and less extroverted. Doyle, Edwards, Dumbleton, Clark, and Cowan (2019) present a study in which two VAs are compared with human interaction. They found eight key dimensions to categorise participants’ perceptions, for this study is essential to quote at least three of them: conversational interactivity, partner identity & role, vocal qualities. MA, Yang and Fung (2019) used the Big Five model to understand whether VAs personality affects how people perceive intelligence of Vas; their testers observed VAs
endowed with personalities more intelligent than the robotic one. There are still a few examples of how to design the personality of a VA. Spencer, Poggi and Gheerawo (2018) designed, through participatory design workshops, four personalities based on Jung (1954), Person and Mark (2001) archetypes. They define four main features: purpose and story, person, tone of voice, language. Lee, Lee and Lee (2017) show the results of workshops with groups of two users that play the human role and the VA role, using the Wizard of Oz approach. They found that if the VA role was acted in a cheerful and friend like users were funnier and more satisfied, even if the time to complete the tasks were longer. On the other hand, groups with introvert played VA had the best performance with a minimum level of communication. Ghosh and Pherwani (2015) observed the behaviour of assistants in real life. They collected data about communication styles, attitudes, language and nonverbal cues, strategies to face the boss mood. Then they selected nine personality attributes to generate three hypothetical personalities. This work is significant, but, according to the authors, is focused on the assumption that a VA could be only an assistant and must act mimicking those behaviours. Heudin (2015) designed an emotional metabolism that can manage personalities, moods and emotions into a multi-personality conversational agent. He experimented 12 personalities, some of them referring to characters of cinema. He claims and demonstrates that multi-personality agents work better than mono-dimensional ones preserving coherence. Finally, Braun, Mainz, Chadowitz, Pfleging and Alt (2019) propose to match the personalities of users and VA using Big Five models and experiment them into a real-world driving study. They designed four assistant personalities (friend, admirer, aunt, and butler) and their results show "higher likability and trust for assistants that correctly match the user's personality while we observed lower likability, trust, satisfaction, and usefulness for incorrectly matched personalities". The interesting part of this work is the use of a voice pre-recorded by an actress. In the literature review, the authors found some work about the characterization of the interfaces, starting, for example, from the work of gender analysis by Schnobelen (2016); Luria (2018) suggests three guidelines to design personal robots: reciprocity, affirmation and independence. These come from a review of 15 sidekick characters from popular books and movies. Literature analysis shows that there is still a little corpus of studies about the designing of the personality of interfaces in general. The authors also found that is not clear how to design the behaviours of a voice according to the users and the context, finally even if it is true that people consider VA as human-like there is still a design space to project an AI character giving to machines their characterization. According to these brand-new studies and previous experimentations, the authors want to explore the characterization of the interface and the concept of performing interfaces which is recently be claimed by Aylett, Cowan and Clark (2019), underling the differences between personality and characters. Therefore, considering personality aspects is now part of the design process but as Vas are considered human-like can they be considered as characters? Which elements besides personality are needed to design VA in this way?
3. Methodology and Workshop structure

The experimentation makes use of designed theatre workshops that aimed of showing and understanding the main features of a vocal interface and creating a grounded common language background between performers and designers. The workshops involved three professional actors, they currently work for theatre shows and film productions, they also recorded voice over for films. The elements of discrimination to choose them were: their experience in shows where the contact with the audience was much closer, for example in contexts without a stage and barriers between actor and audience; their work as teachers. We assumed that the closeness and direct interaction with the audience, greatly influences the character and generates sudden changes during the performance, then teachers of acting methods have experience in explaining all the facets of the theme. The three workshops with the individual actors lasted about three hours each, they took place at the authors’ department, both the authors took written notes during the workshop. We chose not to record audio and video, except for brief moments related to performance examples, in order to avoid that the actors could perceive the workshop as a set. The first phase focused on the voice assistants currently available on the market; the goal was to: verify the actors' knowledge of the interfaces; acquire familiarization with them; investigate their use; test the other devices they were not aware of; collect their perceptions on the voice assistants asking them which were the main perceived parameters and if they found the features of a character designed as such. The second phase concerned a critical analysis, in which the actors were asked to comment on three vocal interfaces chosen among the many present in the cinema (Samantha in Her, HAL9000 in 2001: A Space Odyssey, the episode White Christmas taken from the Black Mirror Series). The aim was a deeper understanding of how a cinematographic interpretation of an AI was designed and realized and to trigger a dialogue on character building. The third phase mixed elements typical of the semi-structured interview and the performance. The actors were asked to explain not only the main factors that allow to characterize a character during the performance, but also the developing method itself across different steps. This framework could also be useful not only in the preliminary phase, as in this paper, but it could be also used for concept generation and validation. In fact, the general goal is to better understand how performing a character is different from considering personality as seen in literature, in order to obtain other parameters to integrate into the design process.

4. Results

During the first phase all the actors confirmed that they know at least one of the vocal assistants, but they do not own them as speakers. One uses Siri on iPhone weekly, one Google Assistant daily, one Google Assistant only in particular situations (i.e. driving). The actor using Siri started to do it after a random event. During the rehearsals, Siri started talking without anyone wanting to do it. From that moment, Siri was used as a character on
stage as a disturbing and surreal element. All actors previously seen Alexa at work, none of them ever interacted or listened to Cortana’s voice. In order to demonstrate how the four VAs work, the actors could freely talk to the assistants for few minutes. Then actors asked to the VAs to tell a fairy tale and sing a song. This choice allowed the actors to listen to two possible uses of the voice closer to their context. For all four cases the actors were asked to evaluate the vocal assistants according to the criteria of verisimilitude, and the parameters associated with the voice that were more evident to them. The comparison with the parameters is based on the literature and includes tone, timbre, pitch, rhythm, intonation, accent, prosodic elements. The three actors recognized as plausible Siri and Alexa, praising the quality of Alexa’s voice, while judging the sound quality of Google Assistant and Cortana as still “too raw” and “robotic old school”. Judgements about the characteristics of the voice were: "always UP", "always ready and enthusiastic", "ringing". It should also be pointed out that one actor emphasized that all these characteristics reinforced negative stereotypes related to female gender. The three female voices were also defined as the mirror of current technology. According to the actors, it seems that the voice that represents the intelligence of the machines has that particular timbre. The reaction in front of the fairy tales and songs of all three actors was of "amazement", "makes you smile", "could be used as a pastime". Vocal assistants told: a text about punctuation (Google Assistant); the little mermaid (Alexa, NB with sounds and accompanying effects); the fox and the grape (Cortana); Siri avoided answering. By repeating the experiment, some of the VA can change behaviours, Cortana sometimes answers similarly to Siri and Google Assistant, telling their own story. The actors highlighted that this might contribute to the construction of VA back-story. The songs, instead, have been an element of debate, especially about Cortana (Italian anthem) and Alexa (Il canto dell'addio). The actors expected that VA would use a tone modulation effect, called vocoder, and that they could not keep up with the rhythm of the song. But voices and rhythm were not distorted, so actors assumed that a speaker recorded the songs ad hoc. Google Assistant’s voice, instead, collides with the actors’ expectations because it sings nonsense lyrics; while Siri refuse to sing and after some insistence provides a spoken version of the song “Nel blu dipinto di Blu”. The songs provided more elements on the analysis of the parameters of the voices, i.e. the rhythm, the cadence and the tails of the vowels. The rhythm is perceived by the actors as "broken", "not fluid", especially when the period becomes very long. In their opinion this depends on a cadence that is not yet fully characterized, but above all on the vowels cut in the length at the end of the words. If, in fact, the addition of some pauses and hesitations, such as "ehm", recalled probable human behaviour, one actor pointed out that the word can be pronounced more or less quickly, but very rarely is cut off sharply. The question at the end of the first part concerned the perception of a designed character in VAs. In this case all the three disagreed, pointing out the total lack of acting and of typical aspects of the character, defining the interfaces as "generalist", "average", "not at all prone to make the interlocutor emotional", "distant, though always cheerful and available". When asked to compare their comments to the personality classifications found in literature, actors agreed on their utility, but they pointed out that personality is not "rock-hard", it has to be declined in every single line and actions;
Artificial Intelligence is a Character? Exploring design scenarios to build interface behaviours.

so, it is not possible to apply personality just to a question-answer, but it needs more connotation as a whole character. They underlined that a character needs more psychological elements – personality is just one of them –, physiological and sociological features in a complex way. The second phase was dedicated to the analysis of three videos that clearly show the interactions with artificial intelligence. The beginning of this phase was dedicated to watching some part of films in English and Italian language. The first sentence that all the actors uttered was almost identical “this is acting”, "we are talking about something else", "it is not comparable". The actors underlined the strong interpretation highlighting the unbridgeable difference between actor and speaker. Although some subjects of actor and speaker courses of study are similar, actors are called to work with their whole body "in a holistic way", while speakers can work only on aspects of voice. Explaining better those concepts, actors focused both on the vocal emission through the body and its movements, and on the psychological aspects. They performed some lines showing how that interpretation could be generated by focusing on the invisible body of the actor, for example "even if you can’t see the body of Scarlett Johansson (Samantha's voice in the film Her), you can perceive her posture, her gestures, you can hear her breathing". Two of the actors narrate, in fact, that in order to emit sounds in the theatre it is necessary to involve the whole body, that is used according to postures, movements and gestures to limit, amplify or modify the sounds, even stage costumes are taken as a cue to characterize the vocal emission. In the theatre, the psychology of the character is explored in an extremely detailed way and the indications are often metaphorical, "that sound must be yellow". Sentences that seem to recall Kandinsky's theories and that, however, could generate a common background language starting from design elements. All the actors agreed on another determinant factor of the acting: it can return the change in the psychology of the character. "You can understand what Hal9000 is becoming paying attention to how the interpretation is changing, the rhythm, the sound, how it plays between the mellifluous and reassuring register and the attitude of the one who hold your life in its hands". The voice reacts to the narrative, to the evolution of the characters during the whole time. One actor, commenting on the scene of Black Mirror, dwells on the fact that it is the man who tries to imitate, to impersonate the role of the machine, as if the machine now had a predetermined archetype. The third phase focused on two questions: how an actor builds the character to be performed on stage and how, once on stage, he modulates and manages everything he has studied. The answers were very different, many methods and schools of acting were mentioned and often the answers remained on a high level, the same about the voice parameters. Three phases emerge: study and construction of the character by themselves, adaptation of the character during the rehearsals with the director and the other actors, live performance. During the first one the answers have common traits when quoting the questions towards the character. This is a technique widely used in writing (Seger, 1990), whether it is dedicated to novels, films or theatre performances. It is an approach that can also be found in character design and concerns the exploration and research of the character, starting first with the written text analysis and then adding levels of depth on all possible aspects of the character’s life and story. When a detail is not present in the text, the
actors reconstruct it. This serves to build the internal motivation, “the engine”, the goal that will become increasingly evident on stage. The reconstructed elements will help the actor in shaping the character. On the basis of the text and the questions to the character, the actors declare to build "a scheme", "a grid" that includes all the elements, from the dominant emotions to the recursive gesture (e.g. of the hands) constructing a recognizable grammar of the body, from the parameters related to the voice to the relationship they will have with the other actors. The second example has been defined "the jazz grid" and is linked to the other two phases of rehearsal and live performance. The actor builds the character on a "reactive grid", with possible responses to other events. As in jazz improvisation, the interpretation becomes relational. The grid then responds to the input provided at that moment by the other actors, by the audience, by the context and by the environment whether real (in the street or in houses), or on stage. A clear distinction emerges between these two environments. Although the actors on stage claim to perceive very well how the audience is reacting, in situations without barriers the actor enters a direct relationship with the nearby audience and modulates the parameters of the grid by virtue of the audience's attitude. In these cases, they say that the range of variation of the parameters is much wider to better adapt, provoke, seek empathy with the audience.

5. Conclusions

The actors' vision was very much concerned with qualitative aspects of performance. Aspects not found in the literature and divergent ones appear in all three phases of the workshop, from the use of the whole body acting to generate the voice, to the need to build the psychological aspects of the character, starting from his relations and his story that evolves during the use. The lack of characterization of VA is highlighted, as a homologation on many aspects. Furthermore, some purely vocal aspects must be implemented, such as the final resonance of the vowels and a design of some distinctive features such as rhythm and cadence. It is difficult from the analysis of these workshops to draw precise variations in order to obtain immediate results applicable to the existing vocal interfaces. According to actors the project is missing, although the vocal instrument is at an advanced state of realization and their producers are exploring innovations such as emotional intelligence, which may not fill the aspects of emotional reaction. The three workshops, on the contrary, allowed the authors to glimpse what could be a road still little explored regarding the question: what is the character of technology, of artificial intelligence? Cinema and visual arts provided many answers designed to stimulate reflection, trigger discussion and provoke, but by now the technological tool is already present in our homes and in our habits. Personality aspects can be considered a starting point but, as actors pointed out, using only personality the risk is to obtain a homogenisation of the interfaces’ behaviours. To create real emotional conversational VA, the next step should be the construction of a complex character able to react during the dialogue, according to the situation and the context. The contribution of design in this field can therefore be very methodological, if it integrates not
only actors for performance but also copywriters, psychologists and social science experts in a wider way.

6. Future Works

The presented work is part of a research project that will end with the design of an interface for a self-driven vehicle. The next step will therefore concern the definition of some possible characters that AI will be able to interpret in a well-defined context, the script writing and interpretation of the actors and the subsequent post-production actions that are still open questions.

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Artificial Intelligence is a Character? Exploring design scenarios to build interface behaviours.


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Becoming Janus: The Subversive Potential of Face Recognition Technologies

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Abstract | The human desire to “know the face” and to decipher its diverse characteristics and manifestations has long inspired technologies of vision. In recent years, it increasingly stimulates scientists and engineers in efforts to automate vision: to create machines that can not only generate images, but also analyse their contents. Consequently, “machine-to-machine seeing” (Paglen 2016) is dramatically transforming multiple spheres of human life as it also removes humans from decision making. Protesting against the growing threats of such technologies to society, artists, designers and activists straddle the lines between machine readability and human recognition in a call to resist what they refer to as total surveillance. This paper explores such efforts to reinvent and subvert facial recognition technologies. It delves into the differences between identity, identification, and social acceptability, paying particular attention to the way these differences are manifested at the conjuncture of visibility, machine readability, and human recognition.

KEYWORDS | FACIAL RECOGNITION TECHNOLOGIES, SURVEILLANCE, CRITICAL DESIGN, BIOMETRICS, IDENTITY
1. Introduction

*When you invent the ship, you also invent the shipwreck; when you invent the plane, you also invent the plane crash* – Paul Virilio

In Roman religion, the god Janus was considered the animistic spirit of doorways (*januae*) and archways (*jani*). Some traditions regard Janus as the god of all beginnings: the beginnings of the day, month, and year were sacred to him. Janus was represented with his face turned simultaneously backward and forward, seeing into both past and future.

In modern times, Janus is the name given to the facial recognition initiative of the Intelligence Advanced Research Projects Activity (IARPA), a US government body that funds innovative research aimed at giving the US intelligence community a competitive edge. Its goal is to enable “dramatic improvements in unconstrained face recognition. . . to develop novel representations to encode the shape, texture, and dynamics of a face for the purpose of improving face recognition performance from video and still images, and then allowing higher performance search and retrieval” (IARPA 2013). In an age when facial recognition technologies (FRTs) are becoming omnipresent, the duality captured in the project’s name is revealing, if not alarming.

The IARPA Janus Project is but one instance of so-called “soft surveillance” (Hudson 2013). Airlines now have facial scanning instead of passports for boarding; fast food restaurants use it at their front counters; and Apple uses it to unlock its iPhones as well as its Apple Pay app. Soft surveillance gains compliance by persuasion, rather than coercion, yet still denies the individual any meaningful choice (Ball 2009). The situation is aggravated, however, in non-democratic countries. In China, for example, ordinary citizens use facial recognition to pay the subway fares and sort the garbage, while the government uses it to actively monitor them. These examples demonstrate the rise of FRT and raise concerns regarding threats to freedom and privacy in democratic and non-democratic countries alike.

This paper examines the costs of the digital stabilization of identity that follows biometric analysis, the tension between digital identity and individuals’ power to shape their own, and efforts by theorists, artists, designers, and activists to resist the quick adoption of these technologies and call to regulate them. Select examples from their work invite us to imagine a future that undermines the rigidity of today’s political and corporate digital hegemony and propose alternative narratives to current uses of FRT.
2. Know Thy Face

Faces are considered the most personal and distinctive feature used to identify and recognize others: they are information as well as expression devices. Recently, with the dramatic increase in the adoption of face recognition, detection, and analysis technologies that rely on powerful software platforms, serious legal, public advocacy and philosophical concerns have arisen. Unregulated, prone to human error and systematic bias and above all poorly understood, FRT is rapidly rolled out in fields as diverse as military intelligence, policing, and consumer culture. An advanced recognition system has to be in place in order for a face to function as a gateway to unlocking devices, enabling services and payments, and crossing borders. FRT does not operate only as a static database focused on ad-hoc individual identification, but is increasingly used in real-time, nonspecific dragnets, or “face surveillance”.

A recent significant FRT breakthrough is the emerging field of automated facial emotion measurement and expression recognition, designed to infer feelings. Most emotion recognition systems are based on research conducted by psychologist Paul Ekman in the 1960s. Following Ekman’s concept of a shared vocabulary of human facial configurations that are tied to emotion, stating that many of which are universal, subsequent studies have assumed a consistent, species-wide map connecting certain expressions to certain emotions.

More recently, artificial intelligence (AI) and machine learning (ML) have been applied to “understand” the context of human behaviour by analysing facial expressions and gestures. Moreover, their deployment responds to this “understanding” in ways that can support human life, health, wellbeing, and recreation – but also marketing, prison and mall security, and state surveillance. Both emotion and facial recognition systems rely on capturing facial features and reactions, but are “trained” on datasets that are often flawed. Indeed, whereas data on the human face has quickly become a commodity, laws and regulations lag behind and in their absence, the use of recognition technology poses complex ethical dilemmas regarding transparency, algorithmic governance, fairness and accountability – and ultimately, data privacy and human rights in general.

Biometric identification systems that aim to “authenticate” individuals usually do so by digitally scanning physical traits. Face recognition is one such example, and so are iris scans and fingerprint matching (Pugliese 2010). Relying on these technologies for authentication requires considerable caution once our society accepts what is extracted via computational means as biological “truth.” Kelly Gates (2011) argues that digital biometric identification technologies are designed “to fulfill certain perceived social necessities and political-economic demands of large-scale, late capitalist societies – societies characterized by a predominance of mediated forms of social organization and vastly asymmetrical distributions of wealth” (p. 16). For Gates, the premise of automated facial expression analysis is “to make human affective behaviors more calculable, to open them up to precise
measurement and classification, thereby making them more amenable to forms of intervention, manipulation and control” (p. 22).

In a similar vein, in *When Biometrics Fail*, Shoshana A. Magnet (2011) sheds light on the role that state institutions and the military play in driving technological development and criticizes the close relationship between surveillance and marketing. She asserts that human bodies are not biometrifiable, and that biometric science presupposes the human body to be a “stable, unchanging repository of personal information from which we can collect data about identity” (p. 2). Her argument is part of a long tradition that believes that any such formalization process involves a reduction in complexity (Goriunova 2019). Magnet is concerned with the kind of society we will become once we deploy these technologies, where a form of representation comes to be understood as a techno-scientific truth.

Given the dependence of biometric technology on both machine vision and ML and taking into consideration the threats they pose to human rights and basic freedoms, FRTs’ shortcomings and their abuse by states and militaries should be made public knowledge. Activists, scholars, artists and designers shed light on the fallacies and uncertainties of FRTs as well as their overreliance on paradigms that are reductionist, insufficient, and inaccurate at best, and prone to abuse at worst (see Bjørnsten 2017; Buolamwini 2018).

This multidisciplinary effort is becoming increasingly urgent given the additional layer of abstraction that attaches itself to biometric analysis, with the rise of seeing machines that are both ubiquitous and increasingly autonomous. In fact, most images today are produced by machines for machines to see, process, and label. As a result, most images produced today are exclusively machine-readable, never seen nor intended to be seen by humans. This machine visibility that is invisible to humans has two major consequences: (1) We do not know where, why, by whom, and for what reasons these datasets are culled; and (2) Citizens and computer scientists often do not—and cannot—understand the workings of the machines. Due to the blackboxed nature of the algorithms involved, even those in charge of their operation are only partly aware of their decision-making and inference processes. We hear more and more voices of criticism warning from the implications of the swift rolling out of seeing machines and the automation and black-boxing of the process that govern them (Shah 2019, Devlin 2020) and autonomous systems. The time has come to reconsider and renegotiate what just recently became the dominant paradigms in our society.

3. The Blind Spots of the Panoptic Machine

Given the growing concerns with the consequences of constant observability and the degree in which machines intervene in everyday lifegiven the asymmetric power of these systems. We should advocate for new rights, such as the “right to be unseen” not only for data collected and presented about humans, but also for human beings. We see more artists-activists such as Adam Harvey (2019), who advocates in his artworks and writings against
facial recognition becoming “the focal point of an emerging authoritarian logic”. Another bold example is Zach Blas’ resistance to what he considers the violence of biometrics. Blas perceives this technology as a mode of abstraction that has an explicit and unavoidable collusion with global surveillance and the prison-industrial complex (Browne, 2017). Both Blas and Harvey devise tactics and techniques to make faces unrecognizable, or unidentifiable. Their works raise questions pertaining to human creativity and freedom: How can one evade the machinic gaze? Can one possess more than one face? Should we disentangle the link between one’s face and identity, and the way they are captured and represented by humans and machines? How can we escape the abstraction of biometric analysis and effectively resist the machinic attempt to reduce our multifacetedness to a single face?

Social psychologist and techno-philosopher Shoshana Zuboff offers a disturbing picture of how tech giants mine users’ information to predict and shape their behaviour. She coined the term “surveillance capitalism” to refer to the combined market and government trend that undermines self-determination, autonomy, and decision rights “for the sake of an unobstructed flow of behavioural data to feed markets that are about us and not for us” (Naughton 2019). This inevitably leads to a condition she calls “glass life”, where every movement and action is documented. In order to escape the machinic gaze, we humans have to hack the system, to thwart facial recognition software. Zuboff (2019a) warns against a no-exit situation in which walls are made of glass and lauds artists and activists who dedicate their genius to the prospects of human invisibility.

Adam Harvey is among the best-known artists active in the counter-surveillance field. For over ten years, he has been experimenting in attempts to fight total surveillance, but also to create “the future I want to see: people wearing stylish clothes that block surveillance and enhance privacy” (Mali 2013). Harvey’s first works include *CamoFlash* (2008-2010), a wearable set of LEDs that trigger when detecting camera flashes, turning the paparazzi’s tools against them. Most relevant to this paper, they also include *CV Dazzle* (2010 and ongoing), an experiment with makeup and hairstyles meant to confuse facial recognition systems. *CV Dazzle* explores how fashion can be used as camouflage and works by altering the expected dark and light areas of a face (or object) to exploit the vulnerabilities of a specific computer vision algorithm. Inspired by dazzle navy ship camouflage, invented during World War I, it is motivated by the need to reclaim privacy in a world of increased visual surveillance and data collection.

By introducing low-cost DIY methods for deceiving computer vision algorithms, Harvey challenges the face’s machine-readability. Nevertheless, he is aware that the result is very much visible to human observers. “Computer vision poses new challenges that otherwise do not exist in human observation: it is low-cost, scalable, passive, remote, networked, and superhuman in its capabilities to recognize and understand faces, emotions, social relationships, health indicators, identity, socio-economic status (by analysing clothing), and even intent” (Harvey 2019a, my italics). This could mean that we humans must improve our
capacities and become either more or less machine-like in order to trick and possibly overcome the machines.

In a more recent project, *Hyperface* (2013–2017), Harvey exhibits a playful approach to tricking computer vision by creating patterns of false faces for computers to “see.” It proposes a new kind of camouflage that aims to reduce the confidence-score of facial recognition by presenting faces that distract computer vision algorithms. *HyperFace* recognizes that concealing a face from facial detection algorithms is both a technical and an aesthetic challenge. Here, Harvey does not seek anonymity as in *CV Dazzle*, but rather to trick computer vision in a different way. In *HyperFace* he creates a mechanism that offers a higher confidence score for a “false” face by exploiting a common algorithmic preference for the highest confidence facial region.

![HyperFace Prototype](image)

**Figure 1.** *HyperFace* Prototype by Adam Harvey / ahprojects.com. Rendering by Ece Tankal / hyphen-labs.com. 2017

Playing with face properties and visibility has also led other artists, designers and creative technologists to initiate projects that could be easily labelled “speculative” or “critical design.” By calling attention to the different ways that machines and humans “see” and “interpret the world, such works convey how art and design can be applied to raise awareness to pressing socio-technological issues and bring forth a new agenda. One example is a project that straddles the line between social acceptability and machine recognizability:
Wearable Face Projector (2017) – a group project by students from the University of Arts Utrecht. They devised a small device worn on one’s forehead, with a beamer on its front that projects a different appearance on the wearer’s face. The projection blurs facial features and covers them with alternative faces, creating alternative visibility, one that “protects you from privacy violations” as the project description goes (Liu 2020).

Another example, more evocative of Harvey’s CV Dazzle, is the brainchild of Grigory Bakunov (“Bobuk”), director of technology distribution at Russian tech giant Yandex. Bakunov uses an anti-facial recognition algorithm to conceal people’s identities (Zavyolova 2017). Like Harvey, Bakunov uses make-up and coloration as camouflage – not from other humans, but from machines. He draws human attention to himself with the colourful patterns on his face, but they are designated to evade the machinic gaze.

Throughout history, humans invented technologies for hiding and concealing one’s identity, the recent technological progress requires more wit and sophistication in finding ways to tweak, play, expand the possibilities “to hide within technology or turn it against itself. The recent protests in Hong Kong and the ban against masks (The Time 2019) show how in this Janus world of machine visibility, not only do officers of the law seek impunity through anonymity but outlaws seek survival by the very same measures. During the past year, at the height of the COVID-19 pandemic, we have learned about efforts by both governments and corporations to improve facial recognition performance given the universal use of masks (Johnson 2020). Will we be able to find new ways to inoculate ourselves against total surveillance that seems bound to outlive the virus?

The choice to conceal or expose one’s face immediately highlights the differences between what is perceptible to the human eye and what is readable to the machine. In an age when AI systems still need to be “trained” by humans, or at least with data provided by humans, who will train humans to realize the far-reaching consequences of omnipresent cameras and autonomous vision machines?

Some artists, designers and activists take a different approach and go beyond thwarting FRT. Protesting against surveillance, they attempt to protect civil liberties by some form of sabotage or “facial weaponization1”. as Zach Blas advocates in his works. Berlin-based art group Peng! Collective has called for mayhem in the system by blurring the binaries upon which the FRT database are premised. Such a project, if successful and deployed on a larger scale, may impede “the machines and their masters” as Zuboff refers to them. In September 2018, Peng! Collective launched Mask.ID, a computer program to manipulate passport photos, creating a realistic photomontage of two different photos (naturally belonging to two different faces) and “smuggling” them into passports to avoid recognition. Theoretically, the two people depicted can now travel using the same document, because the human eye

1 In his writings, works and workshops, Blas challenges the asymmetrical power relationships embedded in surveillance capitalism and promotes a different kind of visibility devoid of gender or recognizable face.
recognizes both faces in the photo. In an exhibition, Peng! presented a manipulated biometric passport accepted by the Bundesdruckerei (the German federal printing service) that identifies two people: Federica Mogherini (EU Commissioner for Foreign Affairs and Security) and an artist belonging to the collective.

This goes beyond sabotaging the database. Peng! started a campaign calling on citizens to “flood government databases with misinformation” (Peng 2019) and disrupt mass surveillance. The passport, then, embodies the transformative potential of a call to civic action. A contemporary activist rendition of the Janus face, one passport that serves two different individuals is more than an artist’s provocation. *Mask.ID* articulates a very serious idea: the option to hold a double (or multiple) identity or to share one’s identity with someone else. It calls for alternative uses of technology that enable fluidity, resisting the stabilizing logic of one fixed identity.

This proposition can be tested in other fields using technologies other than FRT. Think for example about sharing a credit score, holding a shared voting identity, sharing grades in school, or citizen scores within the Chinese Social Credit System (Kobie 2019). How could the authorities deal with such a situation? Could such initiatives pave the way to undermining the normative logic of the existing machinic-hegemonic order? Is it at all possible to introduce new values such as flexibility, fluidity, or multiplicity in a world constituted by the binary logic?

### 4. Masks and Pirates

Two design projects propose masks that harness rather than merely subvert technology, defying the logic of outlaws and law enforcement to afford both individual privacy and interpersonal interaction. Dutch designer Jip van Leeuwenstein created *Surveillance Exclusion* (2016) – a curved lens-like mask that obfuscates its wearer’s face to fool face-recognition cameras, but not other people. Appearing like a lens, this mask thwarts FRT’s ability to recognize its wearer, but it is still possible for people to interact with the people around the wearer thanks to its transparency (van Leeuwenstein 2020).

*Aposema* (2017) by Adi Meyer, Sirou Peng and Silvia Rueda, is a project conceptualized during their studies in the Interactive Architecture Lab at University College London. Technically, it is a responsive facial prosthesis made of silicone that promotes a new relationship with and through technology – a device that enables a new form of expressive communication. *Aposema* facilitates a more meaningful interaction by two-way transfer of information via the mask. Built using soft robotic prosthetics, biometric sensors and an augmented reality digital layer, this prototype is meant to create a more sophisticated system for creating information ‘inputs’ and ‘outputs’, respectively, enabling and enhancing interpersonal understanding. The designers were interested in possibilities that the mask offers as a means of dynamic
body alteration, which may change its wearer’s social identity. In proposing a new way for communication, one that both reveals and conceals, and offers a more expressive form of communication and interaction between humans and machines, *Aposema* signals a possibility to carve a new, path to self-discovery by means of emotional recognition. In that, it makes an important conceptual step beyond the authoritarian logic of biometric technology.

As explained earlier, the logic that governs biometric technology runs counter the notion that the human body cannot be reduced to a single identity with clear and stable markers. Recently, an in-depth review of over 1,000 studies on the use of facial expressions to convey emotion showed that facial expressions actually provided scant information about a person’s feelings (Barret 2019). In other words, facial movements are an imprecise gauge of a person’s feelings, behaviours, or intentions. There is a growing concern that the speedy rolling out of FRTs and their enthusiastic adoption by corporations and governments neglect philosophical questions concerning the nature of visual perception that have animated theoretical debates about both AI and visual media technologies. As Gates (2011) writes, “if machines can see, they must necessarily embody particular ways of seeing, rather than possessing a universal, disembodied, objective form of vision, outside of any particular vantage point or subject position” (author’s italic).

This concern echoes findings about algorithmic bias and Magnet’s cautions against biometric failures and the fear of science encroaching upon people’s rights by profiling them based on race, gender, and ethnicity. Further research may develop and validate AI’s ability to recognize more subtle muscle movements and contextual cues. Hopefully, it would yield a
more nuanced and more inclusive science, but it will not resolve a philosophical question that is essentially human. It is therefore vital in the meantime to develop alternatives to the hegemonic order —that is, alternatives to the relentless progression (certainly not progress) of surveillance capitalism and to the direction in which technology seems to be headed. Rather than contribute to the cops-and-robbers narrative, perhaps we can develop different pathways that allow digital technologies to serve new masters – privacy, freedom and the individual and social good.

French philosopher Paul Virilio’s theory of accidents suggests that every technology has faults that plague it from its very beginning: “Every technology carries its own negativity, which is invented at the same time as technical progress” (Virilio 1999). The invention of the ship was also the invention of the shipwreck, but also of the law governing seafaring and, I would add, of the pirate as well. What will it take to develop a negative to the existing technological paradigm? Can we turn our face away from the (recent) past to envision a different future, a life that is not made of glass and a face that is not a document? Can we rid ourselves of the rigidity of a fixed identity and strive toward the liberties that can be gained by becoming more like Janus the deity, celebrating duality and fluidity, plurality and change?

The design projects and artworks reviewed here call for a new approach to FRT and for new possibilities for this field. We should encourage and promote additional projects that present new possibilities and directions for facial recognition technology, in hope that it is in our power to transform it, or at least resist its invasion of our privacy. Projects in this vein can and should be attempted for us to build a brave new world where a self-determined multifaceted identity, human and fluid, is enabled.

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Becoming Janus: The Subversive Potential of Face Recognition Technologies


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Between digital and physical. Envisioning and prototyping smart material systems and artifacts from data-informed scenarios.

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\textbf{Abstract} | Acknowledging the roles and potentials of data as activators of design processes within the domains of speculative design and prototyping, the authors are running a study fostering collaboration between the fields of smart materials, digital fabrication, interactive artifacts, and speculative design. This paper discusses the possibilities offered when data meets digital fabrication technologies for the construction of smart material systems. Integrating smart components and flexible electronics, novel materials with responsive behaviours can detect, process, and manifest data. Such nature and features make a speculative design approach key for contextualizing these materials in a social, environmental and ethical future dimension to define their purposeful applications. Situated in this cross-disciplinary design area, this paper describes the grounding theoretical framework for the setup of a 2-day hackathon where interactive materials possibilities and implications were addressed and unpacked. Finally, the paper discusses potentials, limitations, and future possible scalability of the experiments and models presented.

\textbf{KEYWORDS} | SMART MATERIALS, DATA, DIGITAL FABRICATION, INTERACTIVE ARTIFACTS, SPECULATIVE DESIGN
1. Introduction

It is nowadays acknowledged the paramount role that data plays in our lives, and as designers, in different ways and for different purposes, we also massively rely on data. For example, they allow us to build data-informed scenarios where to unpack phenomena and understand their features for extrapolating useful insights and suggestions. Given this premise, a team of design researchers from multiple design fields have started a joint research about how envisioning and prototyping can be informed by a conscious and sharp use of information as data, following a Research-through-Design paradigm (Frayling, 1993; Koskinen et al., 2011). Here, by data we refer to those related to existing imaginary as films, television programs, home videos, video games, streaming contents and other media that can be accessed because available online. As designers, we look at such relevant and valuable information because they can be seen as clusters of knowledge with the potential to play a key role in igniting and harbouring scenarios, elaborated in narratives and imaginaries (more or less wide and shared). Those data are often difficult to be retrieved, accessed, or identified as relevant because they are dispersed in the vastness of the online material.

Building on this, we launched InData (www.indata.polimi.it), a project aimed at investigating the role and potentialities of data as activators in the design process identifying speculative design and prototyping as its application fields. This project was born with the scope of enabling designers to better imagine possible futures, exploiting the collective knowledge coming from online open databases. The main practical output of the project is a Scraping Tool (Varisco et al., 2019) that plays an important role as a data collector and organiser, allowing access to knowledge that would otherwise be more distributed, or worse inaccessible. Within this project, we conducted several experimental activities, led by the research question: How envisioning and prototyping can be informed by data?

Here we discuss the possibilities offered by the encounter of data and digital manufacturing technologies for the construction of smart material systems in a perspective of envisioning and prototyping. Speculating about possibilities is indeed an empowering way of disclosing and discussing alternatives, considering both utopian and dystopian perspectives (Auger, 2013; Tharp & Tharp, 2019). Acknowledging that data and data-informed scenarios can be fundamental triggers when properly embedded in speculative design and prototyping, the experimental part of our study consisted of a hands-on activity, in the format of a design Hackathon to correlate the fields of smart materials, digital fabrication, and interactive artifacts.

In the following we discuss the benefits and implications coming from starting the construction of smart material systems from data-informed scenarios, presenting the outcome of a Hackathon where these premises were experimented.
2. Theoretical background

2.1 Interactive and smart materiality

The artifacts we use in our everyday life are becoming increasingly embedded with smartness, as the quality of an object to adapt to circumstances, reacting to different stimuli. Over the years we built complex and interactive systems that bridge together people, processes, data, things, and environments in a networked and responsive way (Evans, 2011, 2012). In doing so, data and information became central for crafting growingly seamless and integrated experiences (Castells, 2000, 2004; Giaccardi, 2015). To respond to this tendency, considering the urgency of connectivity, we should deepen the reasoning on which materials can be used to implement and support smartness.

The expression “smart materials” identifies materials with changeable properties responding to external inputs (Ritter, 2006). Smart behaviours can be transferred to materials by integrating micro-controllers, sensors and actuators into materials so that they can detect, process, and manifest data in very promising ways (Razzaque et al., 2013; Brownell, 2014; Vallgårda et al., 2017; Rognoli & Parisi, 2021). Furthermore, different technologies and materials with smart properties can be combined to create Smart Material Composites (Barati et al., 2018) and Hybrid Material Systems (Parisi & Ferraro, 2021).

The application of such materials unfolds many opportunities both from an aesthetic and functional perspective: enhancing multisensory experiences; monitoring and supporting body activities; making invisible data tangible and information more accessible. One of the main challenges regarding the implementation of smart and interactive materials is sustainability, e.g., using organic and biodegradable materials (Lazaro Vasquez & Vega, 2019; Ferrara et al., 2019; Parisi & Shetty, 2020; Kretzer & Mostafavi, 2021). The use of biopolymers from renewable resources emerges as an opportunity to exploit and test. Therefore, the choice to work precisely on the transformation of bio-based materials into smart bio-based materials is a crucial critical aspect. From a side such materials have not reached a stabilized imaginary; from the other side the possibility to self-produce them in custom shapes, thicknesses, and haptic characteristics, offers great spaces for experimentation and application yet unexplored.

2.2 Speculative design

A speculative design approach is key in contextualizing these materials in a social, environmental and ethical dimension for defining their purposeful applications, by enhancing their potential in translating and delivering information. In fact, such hybrid materials are often materialized in the form of prototypes and experimental demonstrators, due to technological limitations in the case of scaled productions, scarce availability of fully embeddable components in some applications, and a lack of connection with the functional and emotional dimension to which they refer.
With a speculative approach, designers try to envision opportunities without the current limitations of technology, culture, and politics in mind, and seek to satisfy the emotional and intellectual needs of people. Everyday problems often take the shape of complex matters of investigation as *wicked problems* (Buchanan, 1992). Bridging the real and the fictitious into possible or alternative scenarios nurtures exploratory processes where opportunities and possibilities are investigated. These solutions act as a “catalyst for collectively redefining our relationship to reality” (Dunne & Raby, 2013, p. 2). Speculating about the not-yet existing technologies and objects, through the use of scenarios or tangible artifacts (diegetic prototypes), is opening new frontiers for exploration and inquiry – critical inquiry and creative exploration. In this way, design practitioners can focus on the new methods and applications through which they can envision a not-yet-existing artifacts and applications. Designers should take a look into the future to face the upcoming challenges. In the area of experimenting with interactive artifacts, intelligent materials, digital fabrication, and speculative design are performing a paramount key role in enabling designers to better imagine the future and to suspend disbelief about change (Sterling, 2005).

### 2.3 Digital fabrication as activators of new possible scenarios

The connecting element between speculative design and new possible application conception of bio-based materials is offered by the enabling nature of digital manufacturing technologies (DMT). These technologies, indeed, are increasingly accessible and pervasive, also thanks to the worldwide spread of places such as Fab Labs and makerspaces. In the last ten years, this led to a change in reachability and exploitation of DMT. The ongoing growth of the maker culture through DMT filled the gap from "having idea" to "making idea" (Dormer, 1997). Nowadays, the importance of experimental practices is not being questioned: throughout design practices the use of makerspaces and fabrication workshops is being actively adopted worldwide, especially in high-education contexts (Carulli et al., 2017). The opportunities offered by making processes not only affect the prototyping phase but can also become a driver of design innovation. Above all, making practices could be identified as the first trigger for enhancing speculation in several fields, not only in Design.

DMT and making processes can lay the groundwork of design concepts that integrate design practices with engineering, art and science. Examples of this approach are “Design Taxonomy” by Ginsberg (2014) that visualized, through 3D-printed shells, a future scenario where vehicles mutate and evolve subjected to biological rules, and “Conus” of Vtol.cc Art Collective, a project that applied the study of a mathematical model to develop an installation that analyses a geometric pattern on shells and transforms them into control signals for the synthesis of sound and images. These artifacts represent singular cases of a wide nebula of conceptual trials and tests distributed in the centre of the *Krebs Cycle of Creativity* (Oxman, 2016), where the creativity drivers are entangled (Brockman, 2011). Consequently, providing the DMT – and more generally the context and knowledge of a university makerspace – the real turning point is channelling the speculative dimension of
design that integrates bio-based materials, sensors, and actuators. A point that should be leveraged when attempting to apply an evolution of the experimental model already present in design schools.

3. Hackathon as a cross-disciplinary practice for envisioning and prototyping

As a demonstration of this cross-disciplinary design space, we present the case study of the 2-day hackathon “DATA <> MATERIALS - Design between Envisioning and Prototyping” involving 19 students from the different courses of the School of Design of the Politecnico di Milano (BSc and MSc). The hackathon relies on a research-through-design approach (Page et al., 2016) thus overcoming the limitations that occur when students have different backgrounds. Such an experimental approach represents a practical way to design where the students are able to first experiment and later quickly verify and iterate ideas extracting the necessary knowledge from the iteration itself through hands-on activities. Experimenting directly by building up ideas in quick prototypes gives the opportunity to fail and iterate quickly, thanks to DMT. When approaching intangible contexts such as future scenarios, the iteration of conceptual ideas in a tangible form is a key element to actualize intrinsic and critical elements. We took advantage of the practical and hands-on design activity as a final step for the InData project research (Varisco et al. 2019; Mariani et al., 2019). We used previously created data-informed future scenarios as a starting point for the student for the creation of concepts. The scenarios served as situational paradigms for the design and as a nourishment for the students’ critical thinking on perspectives of future development and related ethical implications. In the following we present the setting and activities of the hackathon, critically discussing its outcomes and how the theoretical and practical framework nurtured the participants’ knowledge.

3.1 Research methodology

Aiming to understand how data-informed scenarios and digital fabrication prototyping can empower designers in-training in envisioning smart material systems, the research follows a through-design approach (Koskinen et al., 2011). For grasping the benefits and also the implications of exploring bio-based interactive and smart materials from future scenarios and an array of sensors, we applied a mixed method approach, triangulating the results obtained. We monitored the hackathon conducting rapid ethnography (Millen, 2000) with participant observation. Moreover, we asked participants to provide us contextual feedback, explain which processes they were following and why. Further evidence was collected through online questionnaires and informal interviews. Also, we evaluated the experiment through the analysis of the outcomes in the form of the tangible artifacts. The purpose was comparing our initial expectations and hypothesis with the perceptions, thoughts, and experiences of those who partook in the design activity.
3.2 An experimental design method for the cross-disciplinary practice

For setting up the Hackathon, we defined a design method and structured the activities, preparing contents and a supporting toolkit for students. The method derived from the theoretical framework of the project, entangled as a systemic synergy of various outputs and knowledge from our individual research areas. It is a holistic design method involving future scenarios informed by data (Rosson & Carroll, 2009), bio-polymers do-it-yourself making (Rognoli et al., 2015), smart components programming and integration, and digital fabrication (e.g., laser cutting). In this method, three layers are mutually informed to provide design consistency to the designed artifacts: quality, shape, and behaviours (Fig. 1).

![Figure 1. The three grounding layers of the method, and the related supporting technologies.](image)

We involved a heterogeneous, multidisciplinary group of 19 students with various design backgrounds and previous knowledge on the hackathon’s subjects. The brief was the creation of tangible artifacts as outcomes of the application of the method which involved different tools and elements as supporting material for the quick design process: data informed future scenarios, experimenting with bio plastics and digital manufacturing, and sensor and actuators embedding (Fig. 2).

Students were asked to create a concept of a tangible artifact that would set and act in a possible future – a diegetic prototypes – made in bio plastic, with embedded technology, supported by a kit containing a scenario, a board with sensor and Arduino code, recipes for bioplastics, and materials inspiration cards. Additionally, we provided ingredients for cooking bio plastics, and different tools such as moulds and laser cut frames.

Reference future scenarios with the additional support of a Scraping Tool developed by the authors (Varisco et al., 2019; Mariani et al., 2019) were provided as the starting point for students’ creative process. Moving far from the present moment, the act of setting an idea, a concept, a provocatory element in the future allows designers to avoid constraints and boost imagination with a focus on critical elements and ethical involvement.

Moreover, aiming to materialize and iterating the conceptual ideas with hands-on activities, students learnt to create bioplastics with quick and easy recipes that enabled them to give shapes and material qualities to their ideas. The attribution of material qualities to bioplastic making was supported by introductory lectures, tutorials, and material inspiration cards that provided background knowledge and insights for embedding qualities of the material.
through different textures, thicknesses, densities, and so on. Students could take advantage of digital fabrication supports and electronics to be embedded in the biomaterials to give them behaviours and bring actions to life.

The first day of the hackathon was dedicated to the learning and experimenting with biomaterials and electronics that, starting from the data-driven scenarios provided, enabled the participant to explore possibilities and constraints of the creation and use of biomaterials and electronics extracting insights and iterating the design concepts. During the second day, students built the final prototypes.

![Figure 2. Overview of the Hackathon method and toolkit.](image)

### 3.3 Elements of the toolkit

**Reference scenarios.** We provided participants with scenarios that were previously built relying on the knowledge base that later on informed the InData project itself. Starting from information derived from sci-fi, the scenarios are based on envisioning technological evolutions including not only technical, cultural and visual hints but also opening to social and ethical implications (Fig. 3): (1) Perfect Humanity, (2) Pervasive Monitor (3) Automatic Intelligence, (4) Alternatives (Varisco et al., 2017). This formalization of scenarios follows the same principles of the use of the InData Scraping Tool (Varisco et al., 2019), which has also been provided to students participating in the Hackathon as an additional instrument for refining and advancing the given scenarios.
Figure 3. The four scenarios used as a starting point.

These scenarios depict different futures with various extents of pervasiveness and ubiquity of information and technology, showing various degrees of access and use in societal context:

1. **Perfect Humanity.** Advanced technologies and access to high quantities of information enable us to enhance our potential, making us “perfect” but increasing social inequalities.
2. **Pervasive Monitor.** Measuring actions and people in relation to their data enables the hyper tailoring of services, while also raising perturbations on self-
perception, perception of others, and technocratic monitoring of society with political implications.

3. **Automatic Intelligence.** In completing everyday tasks and making decisions, we will rely on machines and robots capable of doing everything on behalf of people. In this setting, people become less and less aware of the actions performed by non-human actors.

4. **Alternatives.** The pervasive connectedness will delete the distances, altering the perception of time and space, and reducing the differences between reality and virtuality. This not only changes our reality but also allows people to become someone else through their avatars and digital representations.

We created a format containing all the scenarios, with mood boards, reference movies titles, and a list of keywords to use to expand the knowledge using the Scraping Tool.

**Bioplastic recipes and tutorials.** For “cooking” bioplastics, we selected a set of predefined recipes (Fig. 4). Participants could create new recipes changing ingredients’ proportions and adding fillers (as powders and pigments), exploring different properties of bioplastics, such as mechanical (elasticity, stiffness), optical (transparency, translucency, opaqueness), and physical (texture). Participants were equipped with laser cut wooden frames of various dimensions to be used for experimenting with first samples of bio plastics. Laser graved textured plastic sheets were also provided for this activity and participants had a half day for testing given recipes. Then they started to design their own frames, textures, and even recipes.

![Figure 4. Experimentation with bioplastic recipes.](image)

**Fab Lab environment.** Access to DMT such as laser cutting, 3D printers, and vinyl cutters allowed to shrink the time usually spent in the production and assembly of study models and prototypes, allowing to run several cycles of error tests until the ideal result is achieved. Without this type of infrastructure available, the duration of the hackathon would have had to be significantly revised.
**Material inspiration cards.** A set of 24 inspirational cards showing examples of interactive and smart materials was provided (Fig. 5). Each card shows an example through pictures and textual information, a short text describing how it functions and performs, and a graphical schematic representation of its components, inputs, and outputs (Parisi & Rognoli, 2021).

![Participants using the material inspiration cards.](image)

**Figure 5. Participants using the material inspiration cards.**

**Arduino, sensors and actuators.** A kit with an Arduino board, sensors, and actuators was provided for the embodiment of the technology in materials and designed artifacts. Based on the evaluation of the complexity and time that has to be employed for the realization of the artifact, we limited the selection to three sensors – sound, touch, and proximity – and three actuators – LEDs, vibration, and buzzers. Moreover, estimating possible uses, we provided basic codes (Fig. 6).

![Arduino coding and experience prototyping.](image)

**Figure 6. Arduino coding and experience prototyping.**

**3.3 Results**

The activity resulted in four concepts of speculative interactive artifacts manifested by realizing a set of responsive material-based diegetic prototypes able to react to inputs and delivering information according to predetermined design scenarios. At the end of the hackathon, students presented their concepts making an open presentation to the
community of designers, where the working prototype was shown and discussed. Here the four concepts are described.

**Secluder.** Based on a society where virtual reality takes over and people live isolated in a parallel world (*Alternatives* scenario), the concept presents a visor-shaped device programmed to respond to noise overstimulation in public crowded environments by recreating a relaxing world of lights and colours regulated by chromotherapy, using sound sensors and LEDs as actuators (Fig. 7). The translucency and the use of colours and gradients recreate a relaxed immersive environment. The light-emitting behaviour and the material qualities are intrinsically dependent, while the texture enhances the interaction between the light and the material.

**h.ID.e.** The team contextualized the concept in a near future scenario where facial recognition takes over and governments have access to all data and control any action (*Perfect Humanity* scenario). In such a scenario, they imagine a part of the population that does not accept giving away their identity for security. h.ID.e is a DIY wearable device to circumvent facial recognition technologies in the form of a mask hiding facial expressions and preventing facial recognition thanks to the material texture and embedded lights activated via touch sensor (Fig. 8). The team exploited the potential of DIY bioplastics for generating uneven surfaces, applying a foamy-effect increasing the number of irregularities on the surface.

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*Figure 7. Prototype of Secluder.*
Breasty. This device is conceived as a companion simulating human skin by touch and appearance (Fig. 9). The team worked on transferring the colour, translucency, and texture of human skin on a flexible bioplastic skin. The device detects the user’s touch through a touch sensor situated on one side; it simulates the user’s touch, vibrating through a servo-motor situated on the other side. Users can interact with the sensing part of the object; in
Between digital and physical return, the responding part will generate the motion that AI elaborated they need (Automatic Intelligence scenario).

**Zhuan.** In the scenario, health and exercise become essential in people’s everyday life, and they are often monitored or assisted by technology (Pervasive Monitor scenario). The concept is a wearable device designed in modules that detect physiological data and it provides light and colour feedback to make users more aware when training (Fig. 10). The team envisioned other opportunities to implement in the future in relation to IoT and communication with other devices for better program and time management. The device modules consist of two bioplastic layers with translucent and soft qualities, integrating electronics in between.

![Figure 10. Prototype of Zhuan.](image)

### 4. Discussion and conclusions

In this paper we presented the theoretical background and results of the hackathon. The method described is flexible enough to be extended or transferred to other fields and aims, and possibly to be scaled out in larger experimental actions. In this regard, we can trace a distinction between the methodology per se and how it was applied. Fundamental elements are data-informed scenarios and their use as triggers for both contextualization and inspiration. The playground in which this methodology was applied is that of smart materials, where scenarios contributed to envisioning the combination of materiality and technology, eventually delivering tangible demonstrators of interactive solutions. However, while in this hackathon the role of biomaterials was a central element, in further activities where the emphasis on this topic is limited, they can serve as a source of inspiration, ideas
stimulation, or materialization of tangible demonstrators. The setup showed the versatility of the methodology, and its possible applicability/adaptability to other hackathons and experiences intended for speculating on times to come while relying on current expectations regarding the future, including societal, cultural, moral, ethical perspectives and implications. The methodology and its tools may be used in activities involving other disciplines or sectors than design or cross-disciplinary teams. Examples are sociology, research and innovation, media studies. In case of this extension to other fields, however, we recognise the possible need to adapt the tools in order to make them accessible and usable by non-designers, as to say researchers and practitioners from other disciplines.

The results confirm that the theoretical and practical framework of the research project can contribute to build knowledge, impacting on the projects’ development. Stimulated by the set of future scenarios, participants developed unconventional and future-oriented ideas of interactive products or materials. The development of the future-oriented design ideas was a reflective process during which the designers were analysing potential societal issues and related ethical implications of the future world. The set of the future scenarios suggested different worlds with alternative social, political, cultural, and scientific constructions, with related implications. Such scenarios also embed several technological solutions that belong to those contexts, serving as the practical activators of the abovementioned implications. Building on this reasoning, the participants were able to explore the fictional worlds that paved the way for better understanding the potential of technologies. In our case experiment, one of the main topics was bioplastics, hence ruminations regarded their possible evolutions and applications, their social impact and ethical implications. The future scenarios and the hands-on activities encouraged the adoption of a reflective approach while facing future-oriented constructions and related idea generations.

All the participants capitalized on the opportunity to use digital fabrication, especially laser-cut applied to wood to obtain custom frames, and laser-engraving applied to plastic surfaces to add designed textured and form to the materials (Fig. 11). The combination of DIY bioplastics as an easily customizable material, and digital fabrication as a rapid prototyping technique supported participants in obtaining personalized tangible interfaces with meaningful user experiences. Finally, the potential of the bioplastic to embed technologies or serve as a layer with the purpose of containing electronics was exploited.

Figure 11. Custom shapes and textures are obtained by moulds laser-cutting and -engraving.
Although we suggested subsequent steps to facilitate unskilled participants, the method encourages a non-linear use of the toolkit’s elements, prioritizing a holistic and flexible approach. Despite the positive feedback collected during the hackathon and in the evaluation questionnaires, some unexpected behaviours were observed, which are food for thought for future actions. In particular, the wide range of interpretative and implementation possibilities offered to students actually shifted the focus from the final output to the process. The experimental dimension is particularly persuasive for design students. As soon as they had the opportunity to confront themselves directly on bioplastics, they partially detached from the final goal of the activity, focusing on basic, extensive experimentation. Probably, the lack of integration of in-depth studies on self-produced materials in design courses was one of the reasons for the deep-rooted curiosity found in the creation of materials.

At the same time, there is the awareness that the acquisition of a process allows its replicability: participants mastered to manage the basic knowledge, potential and limits of bio-based materials, understanding some unconventional application potential of digital manufacturing technologies. In doing so, they learnt that integrating electronic components into a prototype presents unexpected complexities. In this case, thanks to the multidisciplinary structure of the experimentation, participants have been able to expand their knowledge in areas that are not usually tackled together. Therefore, experimentation combined with design practices has once again proved to be an effective and fast learning method.

References


Between digital and physical


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Consensual (Design) Fictions: co-creating iterative use cases to define technology conceptualization

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Abstract | Design Fiction has become the basic tool with which a team of European institutions has addressed the definition of use cases for the project of a future social network called HELIOS. This article aims to showcase this experience of technological conceptualization that has used a co-creation process of speculative figurations as a methodological resource. The underlying HELIOS project-funded by the EU through the H2020 program [http://helios-social.eu]- is a proposal for a decentralized social platform. It proposes an alternative to existing networks because of its context awareness and its connectivity based on trust and transparency. Key findings of this practice-based research show a proto-toolkit on how collaborative fictional narratives are useful in innovation processes. Moreover, it presents a procedure to deal with the complexity of not-yet-existing technologies and socio-technical scenarios. The article highlights some challenges to add ethical, political, and environmental concerns to the technology development process itself.

KEYWORDS | CO-CREATION, TECHNOLOGY, SPECULATIVE DESIGN, INNOVATION
1. Introduction

Every disruptive innovation process requires a leap into the unknown. The first stage of the design process (the conceptual development) deals with fictional devices and situations. It addresses expectations, desires, and preconceptions of what society, especially the relationships between humans and technology, will be.

To succeed, any new product or service needs to consider established cultural and material entanglement. This means creating a stable actor-network (Latour, 1996; Callon, 1998): a set of narratives and a collection of technical requirements that are work and are perceived as desirable and useful both for social institutions and individuals.

HELIOS, the use case presented in this article, is a technology that does not exist yet. Its mission is to build a social network platform on which social media applications can be built. The vision of HELIOS is to empower meaningful relationships by increasing trustworthiness. For this, between 2019 and 2022, the European Commission’s H2020 program, is funding a consortium of 15 European institutions (companies, start-ups, and universities) to bring this technology from the realm of fiction (a concept) towards reality (a tested and functioning technology). The Barcelona based Art and Design University Escola Massana [https://www.escolamassana.cat/en] is one of the consortium members. Massana’s responsibility, through its critical design research team Port 0, is to lead the first phase of conceptualization of the tool to propose a speculative co-design process based on the definition of fictional use cases (Jacobson, 2003).

As a first step Port 0 proposes the capacity of fiction and speculative design to conceptualize a contextual and technological future in which the potential of the product is imaginatively visible. The main characteristics are functionalities and requirements. This critical approach aims to surface the ethical, political, or environmental risks involved.

A creative (academic) team, as part of a technological (private companies and tech universities and research groups) consortium, provides insight into (post-) human centered values and experience that relate to the underlying product (Buchanan, 2004). This initial phase of the design is an open process in which the participation of all project’s partners is required. Fiction narratives become catalysts for a collective empathy that conveys the complexity of the innovation process.

We can summarize the general objectives of Port 0 process in these three aspects:

1. Test the ability of fiction and speculative design to conceptualize and surface future technological performance.
2. Provide a (post-) human-centered perspective for the design of communication platforms.
3. Favor co-creation and manage the participation of all the agents involved in the process.
There are different ways an emerging object can be instituted. In the following sections we will share a particular method that helped a group from 15 different public and private institutions to reach, through fiction-led co-creation, a common definition of a new technology: how it could be, how could it work and how it could be used.

2. Conceptualization context

2.1 Technology design and development in the context of a consortium with several companies and technical universities

During the early stages of technological innovation process fiction emerges related to how the object will be executed in relation to building, producing, using, and explaining the technology. In this sense, prototypes, sketches, and renders produced during the conceptualization stage remain in the world of imagination.

2.2 The role of an arts and design school

In order to present the results of this action-research (Stringer, 2013), we focus on a creative and critical view from the perspective of arts and design, specifically (not limited to) the first stages of the technology design. For this, the approach considers practices from speculative, critical and fiction design, future studies, sociology of science and technology studies and post-human philosophy. This ensures an abstract and open perspective to preferable futures located at the intersection between possible and plausible futures.

These socio-technical projections have been articulated through a (Post-) Human Centered Design practice, particularly by means of scenario building through the iterative co-creation of use cases to inform the technology development teams of (so far fictional) technical requirements and services of this future technology in different contexts.

The findings of this practice-based research allowed us to develop a methodology exploring how collaborative fictional narratives act as a catalyst (from individual imagination to collective empathy) to deal with the complexity of innovative processes and particularly to not-yet-existing technologies and socio-technical scenarios while highlighting ethical, political, and environmental concerns to the technology development process itself. Port 0 conducted this research.

2.3 Particular design needs

As briefly stated above, HELIOS seeks to support the creation of social networks that empower meaningful relationships. To do so, it is focused on two key objectives: (1) to reduce fake content based on creating human trust circles, and (2) to automatically
recognise social contexts while connecting people with similar interests and concerns, through intelligent objects, smart environments, and premium content. The development of this technology implies different institutions from different European countries, working in the fields of computer science research, technology development companies, business and communication, applied technical research and arts and design.

The ‘creative team’ of the project collaborated in the definition of the functionalities, services and uses of the platform to create a framework and a set of guidelines to be technically implemented by the engineering team. This collaboration is part of the STARTS (Science + Technology + Arts) concept [https://www.starts.eu/]. For this, Port 0 gathered all necessary socio-technical requirements for the design and implementation of the overall platform. This included identifying specific aspects that lead to the empowerment of meaningful relationships. The goal is to assess the concept of Trust within social media in order to develop a basis for a platform that follows a ‘Trust by Design’ paradigm.

With this in mind, Massana had to design a process to challenge the ideas of the technical partners through provocative instantiations of what the social network HELIOS could potentially be.

2.4 State of the art

2.4.1 Speculative Design as a conceptual and critical space

Designing a technology is not only about developing an object, product or service, but creating what Science and Technology Studies (STS) define as a stable actor-network (Callon, 1998; Latour, 1996). The execution of a particular connected artifact has to do with its own technical operation, but also with its ability to satisfy a certain range of needs, dialogue with a set of social expectations, and to with the institutional interests. This enables engaging different kinds of users and proposes satisfactory interactions between the human and non-human actors. Taking this into account, the initial steps of a technology design must consider an actor-network in which the object itself will be embedded.

At the beginning of the design practice by Port 0, it was essential to recognise the agency of non-human beings from a post-human perspective (Barad, 2003; Braidotti 2016). This philosophical gesture assists the need to displace the human as the center and measure of everything and recognise other species and ecosystems as ontologically equal, while, at the same time, blurring the boundaries between what is considered as cultural or artificial, and what’s considered natural or technological (Haraway, 2006).

This post-anthropocentric perspective is an essential viewpoint when designing mechanisms for social, political or environmental intervention. In this respect, Critical Design (Malpass, 2017) identifies possible problems or concerns related to objects, products and services within a non-market-oriented perspective. Inscribed within this area, Speculative Design (Dunne & Raby, 2013) and Design Fiction (Bleecker, 2009) are ways of exploring different
Consensual (Design) Fictions: co-creating iterative use cases to define technology conceptualization

approaches to making things, probing the material conclusions of our imagination and removing the usual constraints when designing for massive market commercialization. Inspiration, creative provocation, raising questions, persuasion and innovation are key layers of this kind of practice (Tharp & Tharp, 2019).

Those disciplines consider the future not as something already fixed, but a space to conquer. When talking about times to come, the classical Stuart Candy’s (Candy 2010) future cone is useful in the sense that it provides a series of coordinates considering what is projected, probable, preferable, plausible, and possible.

In order to explore those not-yet-existing realities, Fiction and Speculative Design can help to explore different visions of what HELIOS might be in terms of perception and use, also by incorporating practices and meanings related to the social network. In this sense, this approach is limitless in terms of imagination, therefore the process can furthermore assist in problematizing possible consequences of the implementation of this not-yet-existing technology. The freedom of not having to create something useful, sellable, or even desirable for consumption helps to imagine unexpected possibilities, pushes the boundaries, and helps provoke debate with the technological development team of HELIOS.

2.4.2 Human Centered Design

To frame the concept, especially at the very beginning several authors were taken into consideration to focus on ethical, political, and environmental concerns. This helped the team to build a post-anthropocentric and post-humanist vision of HELIOS.

The philosophical and sociological references were useful to understand the context and link the technology with it, while speculative, critical and fiction design were useful to imagine and problematize HELIOS potentialities. Another design framework that helped to articulate and present complex scenarios, users and, in general, industrial, and socio-technical possible contexts was Human Centered Design (Buchanan, 2004). Based on a series of methods, Human Centered Design situates the core of the design practice in the needs of people instead of aesthetics, technology, or markets to inform the development stage of the project.

Human Centered Design is a wide field with very different methods. It takes into account that, at this stage, the technical team needs be involved in a choice based on the use cases method (Jacobson, 2003), a methodological tool for further definition of computational architecture, technical requirements and use-experience of the platform. Use cases are not exclusively what the platform can do, but narrative examples of some of its possible functionalities and relations with people, objects, business, and environments.

2.4.3 Participatory Design

Finally, taking into account the complexity of the project, it was decided to include the input of the whole consortium in the concept design. To do so we used collaborative and participatory design (Kensing & Bloomberg, 1998; Arias et at, 2000) methods in order to
iterate the proposal several times. The HELIOS concept, therefore, would evolve from a very speculative coordinates to a more desirable, feasible and testable one.

To do this we had to understand what the project leaders perceive as what HELIOS is, and more precisely, what the features and functionalities are. Once the basis was settled, we started a divergence-convergence process. This was necessary to open the partner's imagination while making evident potential ethical, political and environmental concerns related to HELIOS.

3. Design process

Once the wider concept of HELIOS was established, the project partners were invited to further discuss the outcome. More precisely, the stages of this design process were:

- Understand HELIOS core concerns: specifically, the main features and functionalities;
- Use Speculative Design and Design Fiction to open potential uses, functionalities, requirements, and services of the HELIOS platform;
- Use critical thinking and critical design perspective to make evident potential ethical, political, and environmental concerns related to HELIOS;
- Open the definition of HELIOS concept to the 15 consortium partners;
- Use Human Centered Design to create a set of use cases that will work as a briefing that must be checked from the technological team before proceeding to its implementation;
- Definition of the final user-centered design requirements.
Figure 1. HELIOS Concept Design Flowchart
The HELIOS concept design has been developed with a group of students and professors from Escola Massana, working together as the transdisciplinary research team Port 0.

Port 0 started studying the HELIOS project proposal to understand what HELIOS was conceptually meant to be. For this, basic inputs on the general concept of the technology were studied (#1 in the HELIOS Concept Design Flowchart). Once this was understood, the research team reflected ethical aspects of HELIOS, such as potential political concerns, transparency, trust, agency, and environmental impact (#2 in the HELIOS Concept Design Flowchart).

With the core concepts of HELIOS apprehended, the speculative thinking point of view was useful to approach the general concepts without constraints and limitations (#3 in the HELIOS Concept Design Flowchart) with the goal of materializing future scenarios, contexts, uses and functionalities through a practice of Design Fiction (#4 in the HELIOS Concept Design Flowchart). To present and crystalize the possible vision of what HELIOS could be, use cases methods were used. Because the co-design process required to iterate the conceptual prototypes several times by adding consortium partner’s feedback, it was decided to start with 15 different use cases (this number was the result of the initial student’s brainstorming activities). The high level of speculation of this first round of use cases shed light on some possible, probable, and preferable scenarios and functionalities to show different scopes of possibilities.

The 15 use cases were presented online to the consortium for refinement. This was followed by adjustments regarding context clarification, user-centered concerns and functionalities in general terms. Moreover, the Consortium asked to refine technical and feasibility concerns, social concerns, ethical and legal concerns, triggers definition and trust. Furthermore, focus was placed on fantasy avoiding, which means avoid impossible use cases, trying to situate the imagination on the realms of preferable, between the plausible and the possible (#5 in the HELIOS Concept Design Flowchart).

After gathering all consortium feedback, the 15 use cases were redefined with a renewed focus on inter-human interaction, humans-objects communication, and humans-objects-content. Based on the analysis of a new pack of use cases, groups were created and emerged three meta categories related to the central aim or main use of HELIOS in the following contexts:

- Matchmaking (connecting people);
- Smart environment (where the interaction is basically with the environment);
- Prosuming (where users use HELIOS to create, communicate and potentially; market content and services on the platform) (#6 in the HELIOS Concept Design Flowchart).

The definition of these three categories was key to achieve a better definition of preferable HELIOS requirements and services. Based on these categories and a series of key features of the social network like trust, P2P, meaningful relationships, immersive location, virtual
implementation, and premium content, six new use cases were created, leaving aside some unnecessary features. This third iteration was discussed in person with the consortium partners. In the meeting, the consortium identified the need to build simpler, function-oriented use cases while creating a technologies catalogue. Besides, the Consortium discussed technical requirements, human relations values, and testing feasibility (#7 in the HELIOS Concept Design Flowchart). Those requirements were considered to do the last use cases refinement.

The last and fourth iteration of the co-design concept process, ended up with a set of functionalities, technologies, and social requirements. That way, it was possible to provide a framework that might help to create significant human interactions by three different scenarios and functions. Three final use cases were created, focusing on three different areas:

- Connecting People (where different individuals or groups can connect based on common interests or needs).

‘Connecting People’ offers the opportunity to engage with new people, practice new activities or gain knowledge about a certain topic. It is used by people with common interests such as businesspeople, retirees, students, co-workers, singles, etc. In order to connect to other people, each user should activate a set of permissions that will share -depending on what they want to do- personal data like age, gender, studies, real-time location or hobbies with other users.

Helios network could be activated through a (1) user request or established by a (2) smart environment where people practice similar activities (pet-walking, going to a playground, professional co-working, or going to a market, for example). Once the software identifies a potential meaningful, safe, and trustworthy link, it displays an option for the connection that users can accept.

![Ricardo's neighbourhood](image)

**Figure 2.** HELIOS Connecting People Use Case
Consensual (Design) Fictions: co-creating iterative use cases to define technology conceptualization

- **HELIOS Cultural Hub** (where HELIOS works as a social network that links people based on attendance to cultural events).

  ‘Helios Cultural Hub’ works as a social network that links people based on attendance to cultural events. It matches people visiting cultural centers, such as museums, libraries, or galleries, encouraging them to meet each other. It modifies the actual cultural experiences, so they become shared spaces of communication and open-source knowledge and makes connections between users that last beyond the event.

  In that way, libraries and museums become hubs for Helios to engage its matchmaking function. This would be triggered by site-specific beacons whenever users enter those spaces (when they cross a geo-fence). Also, users can agree to receive data and contextually based media about the exhibition or event, that besides provides an augmented and immersive experience of the place. There is also an interactive map of the city where Helios keeps feeding data about cultural places and events updates.

![HELIOS Cultural Hub Use Case](image)

- **Citizen Journalism** (where HELIOS sets a context-aware platform for those who can offer contributions to the description/broadcasting of a particular event) (#8 in the HELIOS Concept Design Flowchart).

  Through ‘Helios Citizen Journalism’ it is possible to publish data (text, image, video) and to access the collected information. There is a content storage/archive where the data is collected and shared. There is also a “Trust Score” and a “Quality Score” of the content, based on previous publications of the user, to avoid fake news.

  The platform can be used as a media broadcasting hub, with “premium content” (pay-per-view) and can integrate a rewarding system for amateur and professional
contributions. Part of Helios contextual network is already established from former editions of the same event. Within the network, users can chat, share content, and make video-calls.

Figure 4. HELIOS Citizen Journalism Use Case

4. Challenges

In learning and experimental environments, Design Fiction and Speculative Design are used to provoke debate, help open the imagination or create objects and services in a coherent manner within a diegetic world. As a methodological process, fictions promoted by design are aimed to visualize concepts, functionalities, or performances of use not easy to be perceived from a standard approach.

Within the framework of HELIOS, these design methods had this same objective plus one: to create an imaginary consensus to clarify the rest of the development process. For this, the use cases lead the journey from the unknown to a consensual known-to-come. The used cases were specifically designed to be an abstract reference and a source of inspiration for the rest of the team to develop business plans, interfaces and, most important, the technical requirements. These requirements were meant to be a list of what engineering teams had to develop.

Through the different iterations of this use cases co-creation process, there were taken into account needs, expectations and limitations expressed by the different partners of the
consortium. Based on those, three usage scenarios were adjusted as a witness of the future social network agreed projection.

The expectation at this moment was that use cases’ co-design process should have stopped. Nevertheless, contrary to what was planned, they became a source of further debate and controversy. The use cases became something they were not intended to be: a design guide, in two directions. On the one hand, use cases are being used for the definition of tasks that technical teams have to develop. On the other hand, they are being interpreted as the script to be strictly used for the testing and piloting of the project. This provoked a new debate on the meaning of HELIOS and has affected the agility of the development process.

This happens often in social research related to design conceptualization and (post-) human centered design which are difficult to guide. Based on this experience, one of the key learnings of this process is the need of designing a knowledge transfer protocol for (post-) human-centered and speculative design processes in technological development. This implies to better define objectives in industrial innovation and to clarify the role of Design Fiction within the whole process including the moments where it can be helpful according to the objectives of the projects and method capacities.

5. Conclusions

The key findings of this practice-based research illustrate a proto-toolkit on how collaborative fictional narratives are useful to deal with the complexity of not-yet-existing technologies and socio-technical scenarios. We highlighted the main challenges to add ethical, political and environmental concerns to the technology development process itself and prevent some of the risks.

Based on this experience, we tested and proved the utility of Speculative, Critical and Design Fiction Methods as an innovation tool in technology to deal with uncertainty in the early stages of development design processes. In this sense, the trans-disciplinary scope of co-design when dealing with the heterogeneity of stakeholders was useful, and collaborative narration was useful to progressive narrowing the speculative scope after the iterative process of co-design.

The design process has surfaced the tensions between the productive objectives of the corporate partners and the search for innovation of academic entities. The iterative sequence of case studies shows a progressive reduction of the idealistic look and an increase in realism in the ideation of technology.

Finally, this experience shows how art and design schools can help foster imagination of technology development projects, opening new possibilities and helping to clarify and synthesize new products and services. In this regard, the need of human-centered design in R+D processes has been proved.
References


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Design of robotic for superhuman tasks

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Abstract | Over the last years, thanks to the latest technological advances, the interaction between user-operator and machine in the industrial context has changed. The presence of collaborative robotic solutions leads to the innovation of production processes and the identification of types of human-robot interaction physical-cognitive, sensory, social and emotional aimed at enhancing human capital.

The paper, through examples of robotic solutions, illustrates critical-analytical processes with a human-oriented approach, aimed at assessing the production performances related to product quality and operator safety in relation to new collaborative systems that follow the evolution of the industry.

In this context, design configures interactive and collaborative working methods in order to optimize the production process by investing in knowledge, rethinking workplaces from a Human Centered Artificial Intelligence (Human Ai) perspective, highlighting both the possibility for human to carry out activities and the possibility for machines to enhance human abilities (Superhuman Capabilities).

KEYWORDS | ARTIFICIAL INTELLIGENCE, HUMAN ROBOT COLLABORATION, SUPERHUMAN CAPABILITIES, MANUFACTURING INDUSTRY
1. Introduction

The new interaction scenario between operators and intelligent machines wants to promote new ways of interactive and collaborative work in order to optimize the production process by investing in knowledge, re-organizing the workplaces from a Human Centered perspective, interacting with technologies and implementing design, production and evaluation methods in terms of predictability, reliability, sustainability and usability. From the analysis of industrial contexts, the greater collaboration between the production operator and the robotic system allows the increase in productivity and the improvement of working conditions by reducing health risks, thus promoting participation through shorter working methods. The presence of robotic systems leads to concrete development of the advanced manufacturing system through the definition of relevant technological trajectories for the improvement of production performance, product quality and production operators' safety in relation to the presence of new collaborative systems that follow the evolution of the industry, characterized by the synergy between robotic and human skills (Krüger et al., 2009).

The significant character is given by the introduction of evaluation methods of Human Robot Collaboration application and by the implementation of industrial automation process with the use of advanced technologies in the process of “Fabbrica Intelligente”, considering the robot system’s comfort use of fundamental importance and the safety for the production operator in human-robot collaboration applications. The integration of artificial intelligence in the industrial robotic sector has the purpose of improving the robot collaborative solutions and “intelligent” workspace optimizing the human-robot interaction. The application of Artificial Intelligence to human-robot interaction system within production process is evolving the concept of work by investing in new skills aimed at smart, sustainable and inclusive growth to improve autonomy in automation processes and respond to new market demands.

2. Theoretical-methodological framework

Examples of robotic solutions illustrate the critical-analytical process starting from the usability, accessibility and reliability assessments of the collaborative systems with particular attention to the safety of the production operator in carrying out work activities in synergy with the robotic systems and the possible implication improvement of production processes. From the analysis in literature of the current collaborative systems and the methods currently available for ergonomic assessments, evaluation methods are highlighted to support the current regulatory system, in reference to collaborative applications. Robotic systems are developed from the identification of system skills, in particular the ability of human-robot interaction, currently among the relevant factors in production contexts.

In particular, the discussion focuses on the design methodology centered on the user of Human Centered Design and on the analysis and design methods for the definition of
Design of robotic for superhuman tasks

parameters and usability principles such as effectiveness, efficiency and use satisfaction, in order to improve the human-robot interaction. These criteria verify, on one hand, the system's quality characteristics, with reference to the present functionalities and their reliability and effectiveness, on the other, the analysis of the interaction, the learning ease and use of the system itself. The performance analysis of the “intelligent” workstations is carried out through the recognition of the current production lines on the basis of the ergonomic principles that determine the well-being in the industrial environment in order to define and improve the requirements and principles of usability of the system in the application of human-robot collaboration (Maurice et al., 2017). The Human Centered Design (HCD) creative approach is centered on people through a process based on human beings’ ability to develop ideas that have both emotional and functional feedback.

The HCD methodology is characterized in fact by three focal moments: inspiration, ideation and implementation. In the inspiration phase, the operator-user is observed during the work activity to understand their needs, identify their priority problems and possible intervention opportunities. In the ideation phase it is understood, interpreted and given a meaning at the moment of inspiration to develop possible solutions. However, in the implementation phase, the solutions are translated into the real context, trying to better understand the communication methods and maximize their impact. The three moments described above are aimed at enhancing and powering up the empathy of users-operators in the workplace and developing innovative solutions in today’s industrial contexts allowing the increasing of productivity.

Figure 1. Scheme of the theoretical methodological framework.
2.1 The evaluation of collaborative robotic system

The evaluation of human-robot interaction is a strongly debated subject and prefigures a greater development technological plan. Evaluate collaborative systems, very often confined to automated operations within industrials installation, it is an issue that involves the robotic production industries, the cobot designers, the institutions that certify the suitability and safety of systems and finally the users-operators that interact directly with the cobots. In this phase is fundamental to introduce the concept of usability, the ISO 9241-11:2018 defines, indeed, the usability as:

“the extent to which a product can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context of use; the effectiveness as a measure in relation to accuracy with which users achieve results and satisfaction as comfort and aptitude for using the product.”

Usability can therefore be expressed through three subcategories: effectiveness, efficiency, and user satisfaction (Weiss et al., 2009). The User Centered Design (UCD) strategy puts the user-operator needs and limits at the center of each phase of the process, providing a very precise development cycle regulated by ISO 13407 Human-Centered Design Process and based on the analysis of users-operators in order to implement systems that meet their needs. The User Centered Design strategy is based on users' empathy in developing innovative solutions and designing experiences. The development cycle of the UCD consist of four phases: specification of the context of use, specification of the requirements, creation of project solutions, and valuation of the projects. The specification of the context of use consist in identifying the user-operators who interface with the robot and defining the conditions of use. The specification of the requirements is based on the identification of the business requirements and the user-operator goals that must be satisfied. The creation of project solutions defines the process' phases starting from an approximate concept to arrive to a complete project. Finally, the evaluation of the projects consists of carrying out usability tests with user-operators in order to test the efficiency of the project; and also:

“Testing users with real users is the fundamental usability methods and in some cases is irreplaceable, as it provides direct information on how people use computers and what are the concrete interface problems in the test phase.” (Nielsen, 1993)

The Human Robot Collaboration methodology changes the projects criteria of collaborative workstations and foreshadows a significant improvement in future production methods. HRC aims to identify the cells that could benefit most from collaborative robotics and to analyze the cells in which collaborative systems have a more auspicious application. The Human Robot Collaboration methodology refers to the ISO 10218-2 of 2011 and the ISO/TS 15066 of 2016 technical specification which defines the collaborative methods and strength related limits of the robots. The HRC is mainly based on the data collection of the performance parameters deriving from the analysis of the ergonomic factors and the position of the user-operator compared to the robotic system in the production line as well as the analysis of times and the logistics system in order to improve performance in carrying out task in a collaborative perspective.
Design of robotic for superhuman tasks

Through the Key Performance Indicators (KPI) it is possible to evaluate the complexity of the technology and the importance of Human Robot Collaboration applications, and to have an overview of the production cells. The parameters arise from the ergonomics of the users, from the operators’ workstations and the interaction spaces, from the line transportation with particular attention to safety and any critical issues, the analysis of the time cycles implemented to carry out the tasks, and finally from the logistics (Zanella et al., 2017). The considered Key Performance Indicator analyze: the shortest cycle times to process the largest number of products in a defined time, the cycles completed by the collaborative system in a given period of time, the service life of the cobot during the performance of a set task, the time expressed as percentage that the collaborative robotic system takes to execute the program, and finally, the waiting time in which the robot is stalled during the execution of the tasks. Therefore, it is necessary to monitor the Key Performance Indicators over time and compare the cobot’s performance during the execution of the various tasks. In this regard it is possible to detect plausible problems and investigate its causes directly from the robotic cell. The KPIs analysis offers the possibility to evaluate the activities carried out by the collaborative system, the methods of interaction between the user and the robot, the exchange information between the man, the machine and the interface. The goal is to optimize the performance of the collaborative cell by making continuous changes and monitoring the KPIs for long periods by investigating in times and activities. The improvement process of the robotic cells is constantly evolving in order to insert robotic systems in the other phases of the process to increase the productivity and quality of the finished products.

3. Regulatory framework

The reference regulatory framework are placed in the field of robotics and in detail it analyzes the Technical Specification ISO/TS 15066 Robots and robotic devices - Collaborative robots which defines the guidelines and safety requirements of the collaborative methods, the ISO 12100 for the assessment of risks arising from human-robot interaction and ISO 10218 for robotic production systems.

In 2016, the ISO 10218/TS 15066 technical specification was born to meet the new needs that emerged from the inclusion of collaborative robotic system within industrial production contexts, the specification provides lists to be respected for risk control and prevention in use of cobots. The technical specification regulates the robotic operating cells according to the different applications without the addition of protective perimeter cages and integrating safety measures on various levels, creating invisible barriers with borders that must not be crossed by the user-operator or, otherwise, the robotic system will slow down until it would shut down. The 2016 ISO/TS 15066 technical specification of Robot and robotic devices - Collaborative robots defines the criteria for assessing the risks generated by the use of collaborative robots and the safety levels that can work alongside operators without danger. The Safety monitored stop connect the robotic systems with the work environments, and in fact it defines the executive phase of the robot that mainly works alone and occasionally interacts with the user-operator. The user can cross the robot workspace, but it is necessary...
to go beyond the safety perimeter to stop the robotic system and perform manual operations. This mode can also be implemented by uncooperative robots. The Speed and separation monitoring regulates the minimum distance to be respected by the operator. The user-operator must respect a certain safety distance and through the use of scanners and vision systems guarantees instantaneous detection, otherwise, the robot will reduce its speed of action until it would stop. It is therefore specified that to make the robotic system more collaborative it is necessary integrate additional sensor and additional safety tools to improve the presence management of the operator within the work environment in order to avoid contact.

The Hand guiding is mainly used to program the movements of the robotic system. The user-operator gets in touch with the cobot to guide the robotic arm and, at reduced speed, plans the desired trajectory through the kinesthetic learning modes. The manual guidance of robotic systems is used for programming semi-automatic movements in safe conditions, therefore it is necessary to have special sensors to protect the user.

The Power and force limiting regulates the operation of collaborative robots through the permitted force and torque levels. Cobots are capable of perceiving the force's abnormal levels, identifying excessive loads, blocking and at the end, dissipating forces in the event of an impact. The robotic systems are monitored thanks to high resolution encoders positioned in the joints that detect the forces and carry out a self-learning process, in this case the robot can stop after the collision or change the direction of movement to reduce the possible impact energy (Vicentini, 2017).

4. Collaborative robotic technologies

There are robotic systems that have been identified, aimed at intelligent, sustainable and inclusive growth, for the innovation of products and manufacturing processes through the application of advanced solutions and technologies for human-robot collaboration within production processes, capable to respond to new market demands. The reference cobots consider the comfort of use and the user-production operator’ safety in human-robot collaboration applications of fundamental importance. In 2004 manufacturer of industrial cobots Kuka introduced its first collaborative robot LBR3 to the market, a very lightweight model with a computerized control system. Instead, the Universal Robots company, in 2008 produced the UR5 model of major importance in the industrial automation field; The CTO and co-founder of Universal Robots Esben Østergaard in this regard states:

“We have been the pioneers of collaborative robotics ever since the term was invented. If it is true that security is essential, today it is nothing but the cost of entering the cobot market. We believe that being collaborative is as important as being economically accessible, so as to reduce barriers to automation and let the robots be accessible to manufacturers who would never thought they could use them.”
The company Rethink Robotics was revolutionary that, between 2012 and 2015, have produced the small Baxter collaborative system and the Sawyer system capable of carrying out high precision and rapid operations. In 2015 Fanuc, the largest cobot manufacturer in the world, has launched its first collaborative robot CR-35iA safe, reliable and capable of lifting up to 35 Kg.

The flagship project of ABB company turns out to be the YuMi robotic system, a small cobot that performs complicated manipulation activities mainly in the assembly stages through the support of the two arms called dual arm. In the ABB product range there is also the YuMi Single Arm model, a cobot equipped with a single robotic arm with an innovative Omnicore monular control system capable of performing assembly operations quickly and with great precision.

The KMR iiwa system from KUKA Mobile Robotics (KMR) consist of the union between a mobile and flexible platform and the lightweight robot LBR iiwa. The KMR iiwa system is an autonomous robotic platform, and to command it a single control system is sufficient. The mobile robot is independent and suitable to be used for changing tools on industrial machines, to power supply machines and automation of laboratories. The KMR iiwa is a sensitive, autonomous navigation system for which no protective fences are required, instead the security system is guaranteed by a laser scanner positioned on the mobile platform and seven force/torque sensors positioned on each axis of the articulated joints on the robot. Thanks to the Simultaneous Localization And Mapping (SLAM) method, the platform locates its position in real time on a map of its workspace generated with data from backup laser scanners and wheel sensors.

FANUC America Corp. has robots that work closely with workers and learn how to work besides moving from one place to another. FANUC mobile robots automatically recalibrate their movements, in fact saving programming times. The CR-35iA robot is capable of lifting up to 35 kg alongside a human operator in safety, increasing productivity and flexibility of the working environment. The robot is characterized by protective rubber casing that protect the operator during the work phases. The CR-35iA robot is the answer to market needs that requires ever safer workspace aimed at human-robot interaction.

The collaborative robot Motoman HC10 of the YASKAWA Europe GmbH company, thanks to a sophisticated force/torque sensor on each axis, is equipped with an efficient safety system when it comes into contact with the operator, allowing a flexible interaction between the surrounding environment and the robotic arm. It should be noted how the robot is compatible with the models of the Motoman range and offers advantages on hardware and controls; they are also reliable and have low interference profiles. Another flagship project of the Yaskawa company is the Motomini with a 500g payload, equipped with a compact YRC1000micro (220V) control system, an innovative Smart Pendant with full touch system. In addition to two cameras, the Nextage Robot by Kawada Technologies consist of a head, a torso, two 6-axis arms with a movable base and a valid safety system where the robotic system's elbows never move towards the outside of the work environment, all thanks to the axial structure, so even if both of its arms are moving, the robot is not in danger of colliding with the user.
The Nextage is equipped with 15 operating axes that use low power 80 watt motors to move, allowing the robot to detect a man nearby, further safety sensors can be installed and when it is essential, this will allow Nextage to stop what it is working on. The UR3e model by Universal Robot has a payload of 3 kg and a radius of 500mm, is smaller and lighter than previous models and is capable of easily carrying out assembly programs and precision work thanks to the 360° rotation on all joints. The UR3e model also features two adjustable safety functions and a new integrated force/torque sensor which increases the sensitivity of the collaborative robot. UR3e is able to retrace a small surface with precise and coordinated movements. The UR3e design is modular, allowing you to replace the joints in 30 minutes to minimize the times, costs and stalling phases of the robot. The K.L.A.IN. robotics, on the other hand, offers the 3D-CPS Fast robot for the bin-picking sector, designed in collaboration with the ISS Research & Development group of Politecnico di Milano, characterized by a guide system for gripping mechanical components randomly positioned. What distinguishes the robot is the system scan speed and a safe and non-invasive IR lighting component for the operator.

Figure 2. Left. YuMi collaborative robot, ABB Robotics. 2015.

Figure 3. Right. UR3e collaborative robot, Universal Robots. 2018.

5. The collaborative robotic and artificial intelligence

In this context, design configures interactive and collaborative working methods by rethinking workplaces from a Human Centered Artificial Intelligence (Human Ai) perspective, offering "artificial machines" the possibility to enhance human capabilities by making them superhuman. Humans are equipped with the ability of self-control, morality, memory and recognition of emotions, in the same way robotic systems, through the use of artificial intelligence, are able to implement human capabilities by ensuring a knowledge of morality higher than that of the average man. In fact, "artificial machines", thanks to their superhuman speed and vast databases, have the ability to help or replace humans when it
Design of robotic for superhuman tasks

comes to making complex decisions. Moral decision making requires the maturation of emotional responses by the reasoner such as empathy, which are properly attuned to the environments and objects with which they relate. It is these responses that allow us to register the true meaning of situations, such as the need to act urgently in situations that warrant the fear of an impending dangerous situation (Savulescu & Maslen, 2015). Thus, relationships and communications are established between natural and artificial worlds without intermediation using multisensory approaches made of gestures, images, sounds, narratives - where robots are able to communicate with each other and with humans, using the same language, verbal or gestural - to understand the fundamental conditions and the necessary decisions to be made or not (Capece, 2019).

In the era of artificial intelligence, the human-machine combination will be increasingly capable of implementing production technologies by enhancing the human factor, improving efficiency, the quality of industrial products and satisfying the demands of a flexible market with short production times.

The Omron company has invested heavily in the production of intelligent robots and integrated and interactive industrial automation system ensuring excellent performance in terms of effectiveness, efficiency and flexibility. The Forpheus robot is a collaborative robot with artificial intelligence designed to train ping-pong players; the interactive system is a representation of Omron's integrated technologies: motion control, artificial intelligence, machine learning and robotics based on open standards. The Forpheus cobot is equipped with multiple movements, greater prediction and detection of human behavior, detection and personalized training of ping-pong players focused on artificial intelligence. Omron has also introduced a new solution for control and preventive maintenance. The Sysmac AI Controller is the first device equipped with artificial intelligence for the automation of industrial machines. The control system analyzes and uses data through Edge devices to improve the durability of the manufacturing plants and prevent any problems or malfunctions in real time.

Another robotic system to mention is Homberger's Doosan Robotics, the compact Mecademic cobot with Solomon 3D vision system. Doosan Robotics is innovative thanks to the integration of Solomon Accupick3D and Mecademic Meca500, an application for recognition, categorization, and pick & place activities. Thanks to the artificial intelligence integrated in Solomon Accupick3D it is possible to carry out the pick & place activity, then identify transparent objects and manage the picking operation from different angles. The cobots, as happens for the human being, store actions through daily experience allowing them to move even in uncertain and unknown environments in order to implement their functions and abilities.
The robotic systems are equipped with Machine Learning capabilities and, without prior programming, they are able to access big data, cloud connection and cyber security, transforming large amounts of data into added value for businesses. According to Machine Learning, collaborative robotic systems are able to learn automatically from experiences through algorithms, in fact cobots analyze the examples to extrapolate meaningful relationship between them. Collaborative robotics associated with artificial intelligence aims to optimize processes with high variance by investing in advanced interactivity, improving decision-making skills and ensuring the possibility of adaptation and self-learning, to make activities less and less repetitive and reduce waste produced by traditional work activities.

6. Conclusions

Collaborative robots represent an expanding trend in industrial robotics, they outline the meeting between human and machine, and the sharing of their respective capabilities and potential. The operator is entrusted with activities of cognitive value related to intelligence and ability to solve problems, while the user-operator is entrusted with repetitive and heavy loads. New interactive and collaborative ways of working are outlined in order to optimize the production process by investing in knowledge, highlighting on one hand the possibility of man to complete the activities, and on the other the possibility of machines to enhance man's capabilities (Arcangeli, 2018). The way to implement human skills is to develop a consciousness in robots to achieve moral thinking; therefore, to achieve this goal, a high level cognitive development that involves processes such as: self-reflection, a sense of trust,
the mental imagination, and the subjectivity, is essential. With this approach the principles of biology and physics can be useful together with current applications of neural networks to improve efficiency and performance (Sossella & Caligiuri, 2019). Artificial intelligence makes possible the learning process by robotic systems through interaction and experience with users within the working contexts, in this regard the cobots are able to adapt their behavior based on the surrounding environment and to cope with unexpected situations.

The task of Artificial Intelligence in industrial contexts is to improve the autonomy of automation processes; through the use of digital technologies, the concept of work evolves to create new skills aimed at enhancing human skills. Collaborative robotic systems with the aid of artificial intelligence will not only be the subject of industrial contexts but will become support instruments in daily life and in domestic environments for assistance and rehabilitation.

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[Vergonomy &design. Design for the ergonomy]


Abstract | Industry 4.0 is a process that has a major impact on production methods and the organization of industrial work systems. With the spread of enabling technologies, workers begin to engage in new types of relationships with intelligent machines. In particular, collaborative robotics (cobots) is identified as an interesting case study to initiate a "human-machine hybrid" design process. Through research based on interviews, questionnaires and field observations, this study aims to define the three main challenges in the design of cobots, assuming the need to reaffirm the importance of a human-centred approach in the smart factory of the future.

KEYWORDS | | INDUSTRY 4.0, HUMAN-MACHINE INTERACTION, COLLABORATIVE ROBOTICS
1. Industry 4.0: cooperation between machines, production department and workers

Industry 4.0 represents a major transformation process which involves a technological leap both in the use of computer science and in the field of industrial automation (Beltrametti et al., 2017). This technological evolution is exponentially increasing the possibility of being able to create systems characterized by high automation, where the human component is of fundamental importance (Celaschi, 2017).

In fact, the application of new technologies in corporate environments does not have effects on production processes only, but also on the way of working, on operators’ skills and on business organization. The use of these innovations necessitates the operator developing new skills, such as the ability to be able to work in a team, to be able to solve complex problems and to adapt to working methods which are different from the standard, managing multiple machines at the same time and moving between different production workplaces:

"these are low-hierarchy organizations, with a pronounced team spirit, with multiple skills and capable of opening themself up to new solutions and new forms of work" (Carvelli & Sapelli, 2018, p.20).

Companies are faced with a profound paradigm shift characterized by a high interconnection and cooperation between machines, production departments and workers. Operators who interact with new technological tools, learn new ways of using and controlling the machines as well as different space management. In fact, the introduction of new enabling technologies will inspire new approaches by operators towards their work tools and new organization and arrangement of lines and machines (Fantoni, 2018).

2. Collaborative robotics

The research project “PReST: Processi, Relazioni, Spazio e Tempo: valorizzare il lavoro umano nella transizione all’Industria 4.0”, conducted by Iuav University of Venice and Ca’ Foscari University of Venice, analyzed and identified the organizational innovations capable of enhancing human work in the industry 4.0 transition in the Veneto region. In particular, the issues concerning organization of work and production processes were studied in depth, with particular interest in human-machine interaction. Part of the research focused on collaborative robotics which represents an interesting case study, as it constitutes one of the fundamental elements of Industry 4.0 in terms of flexibility, adaptability and reconfigurability of production. Collaborative robots are part of an "evolutionary" growth of machines (Magone & Mazali, 2016) that are totally transforming the relationships between machine and user with greater attention to the needs of operators.

This generates new health, productivity and safety conditions in the workplace. From the study and analysis of the current state of cobots (Vicentini, 2017) in companies and their
use, reflections emerged on these products and consequently on their design methods. Cobots are automated systems for direct physical interaction (Colgate & Peshkin, 1999) capable of performing a variety of functions to assist the operator. In practice

“this means that the cobot takes on repetitive and precision tasks as well as the heavy lifting, while a person brings the brains and dexterity to the operation. Cobots, in this way, are literally extending the workers’ physical capabilities.” (Daugherty & Wilson, 2018).

Today collaborative robotics is one of the main development processes of Industry 4.0. To develop it further, it is necessary to involve employees, since the human component represents a necessary and indispensable element for the proper functioning of the company production system. In this context, in which the man-machine relationship is increasingly important and in which a worker interacts with multiple machines, design plays a central role. A process of change is taking place and it is necessary to effectively understand the main transformations in 4.0 development processes and in particular in the process of "man-machine hybrid". (Campagna et al., 2017).

3. The operator as a central element in the design process

Collaborative robots are used to provide automation elements in manual applications with the intention of supporting the operator in order to increase his capacity, depriving him of a series of tasks more suited to machine execution. For example, when it comes to handling very flexible objects and materials with an imprecise shape, the manual abilities and competences of the worker are indispensable. On the other hand, when it comes to handling more rigid elements, the robot can be an "incomparable co-worker" (Vicentini, 2017, p.6).

So, the worker, in the production process is a figure characterized by a high level of importance, because of being equipped with considerable cognitive skills. For this reason, the worker is entrusted with tasks that bring a greater value than those performed by cobots, which are used more in the execution of high-risk operations for users.

Therefore, in order to oversee a complete and efficient design of cobots and all those machines that create an interaction with the human being, it is appropriate to avail of a user-oriented approach (Mincolelli, 2017). The focus is no longer on the automated robot, the machine or the interface, but first of all, it is the operator who must be analyzed to identify the possible ways of interaction that he can adopt in order to collaborate with the machine. Therefore, once the context of use has been defined, the design team must analyze the needs of the operators, in order to create a design proposal capable of satisfying a series of requirements to increase the simplicity and speed of use with the work tool.
4. Research methodology

The research team began an investigation, and a first draft of methodology was done in order to decide on the various research activities. Then a series of interviews took place with various stakeholders, including researchers, trade unionists and company managers, in order to identify which opinions they had regarding Industry 4.0 processes. The goal was to establish a concrete and complete definition of innovations, not only from a theoretical point of view, but effectively researching the main changes in everyday routine and those which occur in individual 4.0 operators. Companies were identified on the basis of specific criteria, in order to carry out internal investigation and observation. Before starting the fieldwork research phase, the research methods were agreed and defined, which were based on 40 interviews with employees, department heads and owners of 4 companies.

Anonymous questionnaires were delivered and non-participant observation was conducted on site in production departments, taking photos and making videos of the work environments, which were useful for qualitative data collection.

The research used a general inductive approach (Thomas, 2006) in order to present findings based on summaries of the data collected through interviews, questionnaires and observations. The analysis of the qualitative data focused on the identification of some "design challenges" that may emerge in the design of cobots to be introduced within 4.0 companies.

This methodology revealed how the operator orientates himself in the use of these new technologies and clarified whether if he favours the new interoperability with machines or not. This approach has proved to be crucial in order to analyze how the worker moves in his work environment and how he relates to new enabling technologies. It was therefore possible to define how all this can impact on the redefinition of the duties of his role and what the possible repercussions are on his psychophysical state.

5. Olmat and Telwin: two case studies compared

From the analysis done, two companies were identified with different characteristics in terms of number of employees and manufacturing technologies in use today. The two case studies are interesting to verify current changes in the way machines and workspaces are designed, specifically through analysis of the differences between traditional industrial robotics and collaborative robotics from the design point of view.

In the case of Olmat, a small metal-working company that produces foundry cores, a traditional industrial robot is used in the painting and palletizing phase. The only collaborative actions between the operator and the machine are identified in the activation and shutdown of the robot by the use of a special display. The man-machine relationship is reduced to these operations and to a remote control of the work, which is performed by an...
interface on the machine. The robot's working space is delimited by a well-defined area to maintain operators' safety and consequently the man-machine relationship is very limited, given that if the operator crosses the robot's working area, the latter will automatically shut down for safety reasons.

In the case of Telwin, a medium-sized company that produces welders, cutting systems, battery chargers and starters, the production line has a quality control and painting management area where a small collaborative robot operates. The main function of this cobot is to spread the resin over the electrical components, thus making them waterproof.

**Figure 1. Example of traditional industrial robot**
and resistant. Interaction with these machines involves a programming officer and others who actively manage machine operation. In the company the employee, in addition to starting and shutting down the machine, performs loading and unloading of electrical components, cooperating with the cobot and actively checking to ensure the work is carried out correctly.

Figure 1. Example of cobot

The analysis and interviews done with employees and company managers revealed that the most efficient electronic components are produced by the combination of cobot and operators and not 100% automated. This interaction allows greater control of production and participation stimulates employees to perform better in terms of both quality and productivity. Consequently work areas take on a different layout: the cobot has no
Design, space management and work tools: enhancing human work in transition to Industry 4.0.

protective barriers and can interact with the user, generating an overlap of the two operating areas.

6. Design challenges: workspaces, physical appearance, human-machine interfaces

The analysis of the case studies identifies some areas of activity in which design can play a primary role, assuming three “design challenges” for the near future within companies in which the relationships between cobots and operators in the same environments will gradually become more complex: workspaces, physical appearance (Follett, 2014) and human-machine interfaces.

6.1 Workspaces

Human-machine interactions increase workers’ tasks and create new methods of using the work tool. In addition, these new relationships involve a different use of workspaces, where the operator, based on the level of collaboration, can share his workspace with the area's cobot (Rhonzin et al., 2019). Specifically, collaborative solutions are designed to generate direct physical interactions with the operator within a shared space. In other words, a space in which the worker and the cobot perform specific tasks together and at the same time. For example, the worker and the cobot can perform different operations without ever meeting or making contact. But if there is a direct exchange of objects or an assisted manipulation of some components, there is a direct cooperation between the human and the automated component (Vicentini, 2017). So, in this case, the space becomes shared: the manual workstations of the operators overlap with the cobot work area, producing more common areas. In fact, in many cases the introduction of new machines involves an important change in the plant layout, especially in terms of space flexibility.

In particular, the introduction of robots in production areas generally brings the operator closer to the robotic system, producing more efficient spaces and unlimited work flows. These collaborative solutions that cooperate with the operator must be monitored and supervised for safety reasons. The cobots are equipped with sophisticated safety devices, such as displays and anti-collision systems, capable of constantly monitoring what happens in their area of operation, coordinating their movements with those of operators, thus resulting in control over their actions and forces used. During the design phase, the designer and all the players involved in the process must try to remove or limit accidental contacts that could be created between the cobot and the operator during the work operations as much as possible.

To do this, it is essential to analyze the cobot’s movements when it is operative and its position with respect to the worker in order to carry out an accurate risk analysis. Since cobots are specifically designed to work with the operator without the use of protection
barriers, it is essential to program these machines in order to regulate their speed in the vicinity of an operator and to insert special locking systems that allow the cobot to be stopped at the minimum contact with the worker and to optimize the operating spaces.

6.2 Physical appearance

A further important aspect to consider for the design of these machines is represented by the construction of shells, which are not only used to protect the internal technology of the cobots but also to confer anthropomorphic shapes (Fornari, 2012).

In fact, for the design and construction of machines that must cooperate with the human being by sharing the same workstation, the design team must be able to design efficient robots, not only from a functional and safety point of view, but also by identifying forms to make operators more comfortable. This is an aspect not to be overlooked, as the intent to give robots human features is not done for simple aesthetic reasons, but to create an interaction that can be as natural as possible, to facilitate and prepare the operator from a psychological point of view into accepting the idea of having an industrial machine at his side more easily. In addition, this helps the operator to perform the tasks with more ease, lowering the level of frustration, the risk of making mistakes and also preventing accidents.

Therefore, the design of cobots and their shapes must start from an analysis of users and all their needs, in order to create design solutions that facilitate operators and their work in a variety of settings.

6.3 Human-machine interfaces

Human-machine interfaces (HMI) play a fundamental role in interacting with cobots, since they are used to make complex systems more understandable and easier to use, acting as a filter between the machine and the user (Aranburu, 2018). In fact, through the interface, the operator can communicate with the robotic system in order to perform a series of actions, including turning on, turning off, controlling and monitoring the machinery. In the design of human-machine interfaces for interaction with cobots, it is necessary to consider all the human variables of the users who approach these devices, through considerable collaboration between all the players involved in the design process: the designer, the ergonomist, the perception psychologist, the engineer. In particular, since it is an interaction process between different types of users, the first aspects that the design team must consider is usability and user experience (Pfeiffer et al., 2016). So, first of all it is essential to analyze the various needs and the cultural and technical background of the user, to establish which functions must be assigned to the machine and which ones to the operator.

In this context, the operator who uses the interface should have the possibility to take actions intuitively and quickly, through a clear and evident arrangement of symbols and messages. For example, if the user has to perform daily interface operations with the device
very quickly, the arrangement and schematization of the signals and messages must be clear and effective.

From this perspective the visual arrangement of symbols and buttons should be coherent, clear and at the same time not too schematic, to avoid generating cognitive chaos, and to make the approach to the machine as intuitive and natural as possible.

7. Conclusions

The analysis carried out highlights the importance of the "dialogue" between the machine and the operator within the new paradigm of the digitized factory. The case studies demonstrate how human-machine interaction, and the design of production spaces are changing in relation to the use of a traditional industrial robot or a cobot. In the near future, collaborative robots will increasingly join traditional industrial robots, allowing a higher level of cooperation with the operator. By taking advantage of direct physical interaction, the operator will be able to spontaneously and safely interact with the machine, with the possibility of bidirectional communication regulated by design.

Considering the important role of design in enhancing the relationship between humans and cobots, today it’s possible to identify at least three major “design challenges”, which can be summarized in workspaces, physical appearance and human-machine interfaces.

In the near future, these areas of studies will become fundamental to define reliable guidelines for the design and development of collaborative robots in industrial sector, in order to augment and enhance human capabilities.

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Designers' Skills for Social Robotics

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Abstract | The discussion about Social Robotics reflects the way we perceive our present and how we envision the future. Social Robots differ in form and function from their factory cousins based on the context they operate in. Social Robots today tackle loneliness among the elderly, aid patients with developmental and degenerative diseases, help perform household tasks and more. The common denominator among all these roles is intensive contact with humans. This contact draws Robotics out of its technical foundations to seek inputs from other disciplines like Social Sciences, Psychology and Design. The potential of the Social Robotics market leads us to investigate the role Industrial Design could play in it, the skills designers will need to cultivate to participate and the strategies for Industrial Design education to ensure the preparedness of new designers for the field of Social Robotics.

KEYWORDS | SOCIAL ROBOTICS, INDUSTRIAL DESIGN, EDUCATION, HUMAN-ROBOT INTERACTION
1. Introduction

*The Neglect of Industrial Design* (Ughanwa, 1991) champions the irreplaceability of industrial designers in product creation. Ughanwa argues that for products to gain a competitive edge in the international market, the design of products cannot be left to the Engineers. Ughanwa’s industrial designer is not a specialist, but someone who can unify a technological capability with the fulfilment of a desire or need of the user.

In the next decade, Borja de Mozota (2002) reports on Design Management in Europe’s top Small and Medium Enterprises (SMEs). The study finds Management employs Design primarily for product differentiation through aesthetic and ergonomic interventions. While the role of Industrial Design begins to be perceived as a major contributor to a market advantage (Drew & West, 2002; Raulik et al., 2008; Europe Economics for DG Internal Market & Services, 2016), the profession is still not considered crucial. In many cases, Design is seen as a sub-field of either Marketing or Engineering. Design is not perceived as a mover in improving product quality or production and most product innovation is driven by marketing, leaving R&D or Design-driven product innovation at a lower priority. The study also analyses what skills managers look for in Design candidates. Imagination and the ability to synthesise and visualize ideas rank much higher than the ability to understand user needs or think laterally. This reflects some of the stereotyping of the designer as more of an aestheticist.

With the advent of Design Thinking around the 2010s, Design as a discipline matured enough to begin influencing other disciplines such as management (Kolko, 2015). Recognising the role of Industrial Design, companies began building in-house multidisciplinary design teams that collaborate with the different departments to create more advanced products (Burton, 2019). Corporations like Apple and Philips that have well-established design teams, helped start the trend of acquiring Design capabilities. Tech players like Facebook, Google and IBM are joined by consulting companies like Accenture, PwC, Mckinsey and Deloitte in acquiring design firms (Maeda, 2016). With the rise of digital products, the focus shifted from products to experiences (Design Council, 2018; Burton, 2019). Consequently, industrial designers now find themselves filling jobs in Design management and User Experience Design (UX) and the profession is adapting to meet the needs of the future.

In the new decade, the growth of Industry 4.0 and the Domestic Appliances market create new opportunities for industrial designers in the technological sector. One of these growing markets is Robotics. While industrial robots used in automated production lines have a well-established foothold in the market, Social and Assistive Robots occupy a considerably small market share. Complex human-robot interactions with these robots demand more thought into their application and usability. As a result, roboticists will need the aid of professionals trained to understand and address user needs- Industrial Designers.
2. Service and Social Robotics

The earliest mentions of Social Robots, in the present context, occur in the 1970s by when the idea of the robot had already been popularised considerably through science fiction literature and film. In a 1978 Interface Age edition dedicated to the theme of robots, F.W Chesson discusses the evolution of robots and lays out the physical and technical requirements for a possible Social Robot tasked with supervision. The article discusses the use of sensors, Artificial Intelligence, and features such as obstacle avoidance that are still relevant to robotics. In the forty years since robots have overcome numerous technological hurdles to make their presence in human lives not just possible but essential.

Broadly, a robot is a programmed physical entity that perceives and acts autonomously within a physical environment which has an influence on its behaviour meaning it manipulates not only information but also physical things (Kaplan, 2005). The International Federation of Robotics (IFR) defines two main services offered by robots: (a) servicing humans (personal safeguarding, entertainment etc.) and (b) task performance and equipment servicing. A Service Robot is thus “A robot which operates semi or fully autonomously to perform services useful to the wellbeing of humans and equipment, excluding manufacturing operations.” (Hegel, 2009). Similarly, the International Standards Organisation (ISO) defines “Service Robots” as robots that “perform useful tasks for humans, which aid in physical tasks such as helping people move around”.

Professional, personal, and domestic Service Robots in 2019 had a combined market share of 17.2 billion USD with logistics and floor cleaning robots making big gains (International Federation of Robotics, 2019). The overall demand for Service Robots is boosted by socio-economic changes (medical, cleaning, entertainment robots) and industry strategies (collaborative, logistics, maintenance robots). As Service Robots grow more ubiquitous, they will have to evolve to adapt and interact more holistically with humans.

In contrast to Service Robots, Social Robots are designed to communicate with people. Chatbots are also designed for that purpose, but a social robot is physically embodied (Korn et al. 2018). Social Robots are explicitly developed for the interaction of humans and robots to support a human-like interaction (Hegel 2009). Bartneck and Forlizzi (2004) define a Social Robot as an autonomous or semi-autonomous robot that interacts with humans by following the behavioural norms expected by the people with whom the robot is intended to interact. If robots are to make this leap, Robotics must grow out of its technological roots.

3. Social Robotics as a Multidisciplinary Field

Roboticists are conventionally engineers with competencies in Electronics, Mechanical or Computer Engineering. These roboticists may also specialize in fields such as Artificial Intelligence, Machine Learning or Computer Vision which significantly augment robot
capabilities. Complementing these individuals are, often, professionals from the fields of Psychology and Sociology, called on to help create the “Human” element of the robot.

Multidisciplinary cooperation in robotics began to gain importance in the mid-90s and early 2000s when events and conferences brought different interest areas, in the field of robotics, together. “The IEEE International Conference on Robot and Human Interactive Communication (RoMan)” that started in 1992 and conducted annually to this day was one of the first such events. Initially, this conference was mainly attended by experts in robotics from technical fields but in recent years the conference has attracted more multidisciplinary researchers. In 2000, the IEEE / Robotics Society of Japan created an international conference on humanoid robots that put the spotlight on robot behaviour and anthropomorphic robots and in 2001 the United States National Science Foundation and the Defence Advanced Research Projects Agency (DARPA) sponsored the first seminar on Human-Robot Interaction (HRI) (Burke et al., 2004).

Such events brought together a highly specialized and multidisciplinary group of researchers who worked in fields associated with HRI and allowed roboticists to interact with experts from various sectors like Psychology, Sociology, Cognitive Sciences, Communication Sciences and Human-Computer Interaction. We can, hence, consider these events pivotal in the establishment of Social Robotics.

Social Robotics has also been advanced by robotics competitions. Two early competitions in the field were the “Association for the Advancement of Artificial Intelligence (AAAI) Competition and Exhibition” and the “Robocup Search and Rescue” (Kitano et al., 1999). The challenges involved the development of robots capable of rapidly analysing their surroundings under extreme conditions and completing their search and rescue task. The rich Human-Robot interactions in these challenges led participants to focus on resolving HRI problems.

In recent years, these competitions have expanded on the original scope resulting in the birth of events dedicated to Assistive Robots. The HRI challenges in this domain include physically supporting the user safely and designing effective social interactions through cognitive and emotional approaches, often through natural interactions like gestures and speech.

These conferences, seminars and competitions highlighted the need to establish inclusive interdisciplinary interactions, to create a common working vocabulary for this field, diversify the areas of application based on the interests of each discipline and organise fieldwork for HRI experts to validate and test concepts. These events also created great opportunities for technology transfer between disciplines and helped identify new opportunities for such technology in society.

The development of robotic assistants in the socio-cultural context poses many challenges. Besides technological limitations (sensor accuracy, actuator response speed, processing capabilities etc.), participation and synergy between the technical and non-technical teams
involved in the project are also issues since the success of the robot is not only determined by technical efficiency but also by its effectiveness (Šabanović et al., 2009). Depending on the context of the application, it is also possible to involve other professionals, for instance, doctors, patients, and caregivers in the case of assistive robots or teachers, students, and parents for educational robots. The design of socially interactive robots can thus be seen as a catalyst of knowledge that can lead to the creation of a “Hybrid Science” (Caporael 2000).

The research covered in this paper is aimed at understanding the present and future roles of Designers in this multidisciplinary field of Social Robotics.

4. Statistical study of Robotics teams today

The first part of the research consisted of the statistical analysis of the role of designers in current Social Robotics companies. It was carried out by web scouting using keywords associated with the design and production of robots. Web scouting resulted in an initial list of 42 companies. This initial list was reduced, excluding industrial robot companies, maintaining companies working on Social Robots. A second reduction resulted from inadequate data found on company websites or insufficient data on the role of team members, their education backgrounds, or their professional profiles. Some of this data was drawn from the interviews we conducted and some from cross-checking team listings with profiles on professional social networks. Another point to be noted is our inclusion of profiles requested for job openings in addition to the composition of existing teams.

Our final sample comprised of 22 representative companies in the field of Social Robotics. They consisted of 1 large, 6 medium, 9 small and 6 micro enterprises. A considerable number of them were spinoffs from research institutes and universities. We analysed employee roles associated with robot development avoiding administrative and marketing roles. We also analysed the educational background of the employees.

Professional roles were classified into 11 categories:

- 3D: 3D Modelling, Animation, Character Design
- AI: Artificial Intelligence, Motion Analysis, Computer Vision, Speech Technology, Sensing
- BM: Biomedical, Human Behaviour, Assistive Technologies
- EL: Electrical and Electronics Engineering
- GR: 2D Graphics, Communication, Web Design
- ME: Mechanical Engineering
- RO: Robotics, Materials, Mechatronics, Energy/Autonomy management
- SW: System Software, IT architecture, Firmware Development
- TA: Assembly, Testing, Maintenance
- OT: Other roles
The different educational backgrounds were classified into 9 categories:

- **BM**: Biomedical Engineering, Physical Therapy
- **CS**: Computer Science, Software Development, Software Engineering
- **DE**: Graphic or Industrial Design
- **EL**: Electronics or Electrical Engineering
- **JT**: Junior Technician, Trainee
- **MA**: Mathematics, Statistics
- **ME**: Mechanical Engineering
- **RO**: Robotics or Mechatronics Engineering
- **ND**: Undefined

From the analysis of data of the selected companies, we obtained 138 professional profiles for comparison. From these, we were able to identify 31 different combinations between job roles and educational background (see Figure 1).

![Figure 1. Comparison of job profiles and educational backgrounds in professionals engaged in the Social Robotics industry](image)

From the graphical analysis, it is evident, at 29% of the total dataset, that software developers with the relevant educational background comprise a significant part of robotics teams. In total, if we consider all software development, including Artificial Intelligence (AI) and other machine intelligence specializations, software developers/engineers occupy around 40% of the total dataset. In the classification we distinguish between the two groups, to highlight the demand for specialists in machine intelligence in addition to developers needed to program functional aspects of robots.

The second most significant participation is from professionals that characterize the sector-Roboticists. Under this banner, we include profiles such as ‘Robotic Engineer’ and ‘Robotic Technician’, professionals who specialise in mechatronics. This role occupies 20% of the dataset and professionals in these roles come from many different educational backgrounds.
The next most significant role is that of User Interface/ User Experience designers (UI/UX), a design specific role. They comprise of around 7% of the team but what is noteworthy is that a greater proportion of these specialize in, or come from an educational background in, software development rather than Design. Only 36% of UI/UX roles in our dataset are occupied by designers.

Altogether, considering the most typical design roles (2D/3D design and UI/UX), which comprise 17% of the total, we note that of these roles 52% of the positions are occupied by non-designers, generally software developers. The only sector where designers are exclusively employed is in 2D graphics, web, and communication design.

The overall picture, though not exhaustive, seems to confirm the fact that, even considering only social robotics companies, which by definition must pay particular attention to the relationship between people and machines, the designer is still mostly required to perform graphic and communication tasks. In the sample, of 8 companies with UI/UX positions only 2 employed designers while the others employed computer scientists. One possible reason for the lack of designers in the industry could be that many small robotics companies are spin-offs from technical institutions and are more focused on functional performance.
Figure 3. Furhat Robotics (Sweden), a small enterprise that produced Furhat (left), involves designers in UI/UX while DreamFace Technologies (USA), a micro-enterprise that developed Ryan (right), has engineers managing UI/UX (Image sources: Furhat Robotics, DreamFace Technologies)

These findings seem to demonstrate that the participation of designers in the Social Robotics industry is not high. To investigate the reasons for this we conducted interviews with professionals in the sector.

5. Expert Interviews

This section of the research was aimed at gathering information from the industry experts on the present situation of design in Social Robotics to synthesize strategies for Design Education in the future. Five interviews of individuals from robotics companies and research institutes, primarily those that deal with Social or Assistive Robotics were conducted: Dr Maria Rosanna Fossati (Researcher, IIT Genova), Mauro Puttolu (Sales Manager, Jampaa), Will Jackson (Director, Engineered Arts), Dr Manuele Bonaccorsi (CEO, Co-Robotics) and Alexandre Colle (PhD candidate, Edinburgh Centre of Robotics and Co-founder of Konpanion). Of the organisations of our interviewees, 2 had in house designers and the other 3 either collaborated with designers on projects or outsourced design tasks. The organizations are based in Italy and the UK.

5.1 What can designers do?

According to Fossati, a designer can play several roles in the Robotics industry. The most common role is that of an aestheticist who intervenes, often in the final phases of the project, to work on the embodiment of the robot. This and the role of the graphic designer
help give the robot a competitive edge in the market. However, this shouldn’t be the primary role of a designer who can also participate as a facilitator between the product development team and end-users to better understand the needs that must be addressed by the product and the end-users’ comfort with the final product beyond functionality. Designers can contribute to robotics through research as well. In literature, Valoten (2005) explains of the existence of these roles based on the evolution of Finnish Industrial Design. The role of the designer as an aestheticist comes from the early days of Design where artists were brought in to create new forms for products. Design Research came with the advent of ergonomics when aspects of the design process were being codified as a scientific methodology and not merely an artistic expression. Designers as facilitators arose in the 1980s with the rise of Design Management and with the rise of the branding era in conjunction with the technological boom, industrial designers became involved in providing User Experiences. Another interviewee Mauro Puttolu feels that this task of improving the User Experience along with Problem Setting are the most important roles designers can play in Robotics. However, his company has seldom worked with industrial designers. It is not uncommon for companies to outsource their design tasks. Hiring a design agency can bring in fresh perspectives, but often, this approach looks at design as value addition and not as an integral part of product development. Instead, in-house design teams require less time to familiarise themselves with the company’s needs as they have a more intimate knowledge of the company’s project, resources, capabilities and market objectives. Will Jackson’s Engineered Arts is one such company and as one of the in-house designers he says, “Robotics is an integration challenge - the mechanical parts must fit with the external appearance and the software interface must be easy and accessible to use”.

5.2 Design in a multidisciplinary approach to Robotics

The collaboration between different fields such as engineering, informatics, natural sciences, cognitive sciences, design, arts, medicine, and education shows how different research methods and work practices are as necessary as they are problematic. Work involving different backgrounds and approaches can often lead to misunderstandings. Confusion over terminology is probably the most common cause for confusion. The meaning of a term may vary depending on the discipline (Šabanović et al., 2007). Fossati notes how the disciplines each have their own language, vocabulary, work practices and toolbox. This makes it hard for the different fields to dialogue, let alone collaborate operationally.

Despite this observation, most of our interviewees agree that the solution to resolve such differences is multidisciplinary collaboration. Jackson identifies the conflict between a designer’s idea and engineered reality as the result of hiring designers with no practical experience and urges designers to experiment and understand feasible production methods and material properties. Manuele Bonaccorsi offers a different perspective saying it is important for engineers to work with other disciplines. He makes a case for interdisciplinary courses at universities where designers come in contact with technology and engineers get to collaborate with designers to broaden their understanding of the application of
technology. This approach will better equip students from both disciplines for professional projects, which are increasingly multidisciplinary. Alexandre Colle, concurs, saying designers and engineers cannot work without each other while developing products. Design, according to Colle, is a holistic discipline where you must consider the needs of users, the environment and the market. Colle stresses that designers must engage more with engineers and advocate the potential of design thinking in robotics. For Colle, multidisciplinary education brings together not only Design and Engineering but also Psychology, Business and other fields that create new opportunities for meaningful outcomes where technology is not an end but a means.

6. Conclusions

Our conclusions on the skills an Industrial Designer should possess to integrate into a Social Robotics development team are based on desktop research on the development of social robotics, studying market forecasts in this sector, analysing robotics team compositions and the educational backgrounds of team members. In addition, expert opinions were sought through interviews. Our conclusions also include our experiences developing Social Robots in multidisciplinary teams (Bonarini et al., 2016) and the courses we teach in this field (Bonarini & Romero, 2013).

6.1 General Skills

Industrial designers’ core skills, as developed in professional courses, will continue to be indispensable in Robotics and designers must be highly competent in using these skills. Industrial designers will have to bank on their ability to identify problems from comprehensive assessments of user-needs conducted through interviews and research. Designers will always be relied on to be creative and solve problems radically. This said industrial designers must be extremely capable at representing ideas through 2D sketches as well as 3D models both physical and digital. Models must not only convey the aesthetic appearance of products but must take due consideration of the production processes involved. To this end, industrial designers must be knowledgeable in the existing industrial methods, materials, and their properties. It is highly recommended that during the iterative prototyping process designers experiment with the materials and processes to improve their understanding of the practical feasibility of their ideas.

6.2 Technical Skills

Robotics development and arguably all product design is inherently tied to engineering. Thus, designers must educate themselves in Mechanics, Physics, Computer Science and Electronics to be able to communicate effectively with engineers in the field of robotics. We do not intend for designers to become experts in these fields but to have sufficient working knowledge of the principles and become familiar with the language used by these fields. A
multidisciplinary approach to problem-solving requires designers to be prepared to work alongside professionals from other fields. Thus, industrial designers must seek experience on collaborative projects, working with engineers, to better integrate into robot development teams. In robotics, designers must be able to produce functional prototypes to demonstrate interactions and basic functionalities. To achieve this, they must be capable of developing electronic circuits employing sensors and actuators or of programming interactive displays. This requires them to extend their knowledge of prototyping to include electronics and informatics. Fortunately, development platforms for electronics firmware and software tools to develop web services and mobile applications, have made this easier today by abstracting many of the complexities. Nevertheless, Designers must be prepared to learn to use new software and we strongly advise gaining some proficiency in computer programming since coding is now an integral part of a broad spectrum of software tools. The rising demand for UI/UX design makes these skills an indispensable part of an Industrial Designer’s toolkit.

6.3 Social Science Skills

Improving User Experiences is heavily influenced by the understanding of human factors. These are studied in detail in psychology, sociology, medicine and design. Referring to research and consulting experts in these areas must be part of the methodology used by industrial designers to create better Human-Robot Interaction. From the perspective of product design, it is evident that the experience of using an object is multisensorial. In robotics, this is even more important considering there are not only affordances from the embodiment to consider but also responses and feedback that must be designed as part of the robots’ behaviour.

There is a great role of context and culture to the success of a project and designers must always be perceptive of the user’s expectations and concerns. This calls on designers to contribute as researchers by staying informed of current trends, market opportunities, technological advancements and scientific breakthroughs in different fields that can lead to new innovations.

6.4 Soft Skills

The multidisciplinary nature of Design positions industrial designers as mediators in the workplace. Visual representation skills that are part of a designer’s foundation has great potential to be utilised to communicate information more effectively between disciplines and departments. Industrial designers must improve their communication skills to dialogue with professionals from different backgrounds as well as to advocate for the integration of design in the development process. For human resources, this ability of designers to collaborate and cross-pollinate across disciplines would be invaluable. Part of the communication skills required is the ability to listen and discuss. Designers must then be able to extrapolate and synthesise the gathered information into new ideas. Lateral thinking is
essential for Industrial Designers to aid in solving technological problems with creative ideas.

Thus, we posit, for Social Robotics still in its nascent stages of market maturity, there is much an Industrial Designer can contribute towards creating new paradigms in robotics and providing inputs that could give Robotics companies a market advantage.

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Designing for the future by understanding evolving culture based on advancing technology and the changing behaviors that accompany it.

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Abstract | This paper will investigate how Design, Culture and Technology have grown in tandem throughout history, how they help us investigate and record the present, and how together, they can inform our future.

1) The Cyclic Correlation between Design, Culture and Technology: Innovation in “technology” ie, not only computers, but the application of scientific knowledge in industry, has influenced the course of Design since our ancestors learnt how to carve bones, rocks and moved to ivory, stone, metal and so on. Our earliest centres of culture, such as the Gobekli Tepe, developed in tandem with Technology and Design (Curry, 2008; Bewan, 2018). Throughout history, the five waves of technological revolution (Industrial Revolution, Age of Steam, Age of Electricity, Age of Mass Production, Age of Information) have been accompanied by social change (Moody and Nogrady, 2010). Design serves as a medium to voice opinions, shape culture and visualise the future. Design can voice the abstract better than words, allowing it to transcend cultural and language barriers. Such expression allows for an alternative discourse that challenges established centres of power, existing norms and helps us expand the collective imagination (Chandrarachud, 2019).

2) Design and the Future: In the 21st century, the influence of technology is felt acutely. It has transformed daily life, it has reduced distance, time, geography; increased accessibility to information and resources and it has consequently transformed our habits and therefore, the content we produce (Brewer, 2018). As technology leaps into increasingly esoteric complexities, Design can help us make sense of our rapidly changing world (Dubberly & Pangaro, n.d.; “Making Sense of Today’s Tech World,” 2018). Design can also make the changes of the future and their benefits and challenges visible to the masses so that we may all weigh in to how technology is going to shape the human condition. We need to cater to and predict the changes technology will bring and design for them. This section will examine design practices today and how they will be redundant or relevant in the future. This section will also attempt to understand the sociocultural changes brought about by technology that influence society and behaviour and therefore, Design

In the purview of this understanding, this paper will outline design as it stands today, including how changing culture impacts designers, design practices and their users/audience, and will speculate the role of design in the immediate and to some extent, the distant future.

KEYWORDS | DESIGN, TECHNOLOGY, CULTURE, FUTURE, BEHAVIOUR
1. THE CYCLIC CORRELATION BETWEEN DESIGN, CULTURE AND TECHNOLOGY

Our earliest centres of culture developed in tandem with Technology and Design (Curry, 2008; Bewan, 2018). Our improved understanding of stone, allowed us to create structures like the Gobekli Tepe, a religious, cultural hub, with carvings to represent interpretations. It has been postulated that these large gatherings pushed us to cultivate grain thereby heralding the advent of agriculture that transformed society and culture (Turchin, 2013). Innovation in “technology” ie the application of scientific knowledge in industry, has influenced the course of Design since our ancestors learnt how to carve bones, rocks and moved to ivory, stone, metal and so on. Throughout history, the five waves of technological revolution (Industrial Revolution, Age of Steam, Age of Electricity, Age of Mass Production, Age of Information) have been accompanied by social change (Moody and Nogradi, 2010).

We see multiple examples of artistic representations flourishing with scientific progress. In the Harappan civilisation, we see evidence of design in the immaculate sewage systems and town planning. The advent of the camera forced artists to redefine what constituted “art”. Artists broke away from realism and we saw impressionism, expressionism, cubism etc. Besides artists and designers using technology, like computers and cameras, to create work, we also see technology facilitating the way work is being shared and experienced. AR/VR is being used in museums and galleries to transform the experience of visitors. (Ricci, 2018; Katz, 2018). In 2017, Snapchat launched an AR feature where Jeff Koon’s AR Balloon Dog was “vandalised” by a group of artists. As technology opens up new arenas to art, we are called to question new perspectives like should AR experiences be subject to the rules of physical space? As the AR experience gets monetised and advertising in this space grows, we would need a fresh set of norms to govern the virtual world (Matney, 2017; Pantelić and Velimirović, 2017).

Design can voice the abstract better than words, allowing it to transcend cultural and language barriers. Such expression allows for alternative discourse that challenges established centres of power, existing norms and helps us expand our collective imagination (Chandrachud, 2019). Chittaprosad Bhattacharya’s illustrations recorded the misery and the role of colonial rule and global capitalism during the Bengal famine of 1943. His work, Hungry Bengal, was so powerful that almost all copies of it were destroyed or confiscated by the British administration (Chandrachud, 2019). Homegrown collectives in India are coming together to offer alternate discourse and express challenging ideas, creating awareness about transgender women, feminism, identity and oppression ("Aravani Art Project", n.d.; “Kadak”, n.d.; Dharmadhikari, 2017).

More famously, Banksy gained international recognition for his work challenging assumptions and questions authority. Following his example of quick graffiti through stencils, teens in Daara kickstarted the Syrian chapter of the Arab Spring. (Chandrachud, 2019)
Given how the arts have been employed as a tool to express dissent, to voice public opinion, to challenge authority, to protest and to start revolutions, they need to be looked at as a powerful tool for change. These movements are gaining momentum through technology, social media and digital imagery and we see Art, Design and Technology shaping culture across the globe.

2. DESIGNING THE FUTURE

In the 21st century, the influence of technology is felt acutely. It has transformed daily life, it has reduced distance, time, geography; increased accessibility to information and resources and consequently transformed our habits and the content we produce (Brewer, 2018). As technology leaps into increasingly esoteric complexities, Design can help us make sense of our rapidly changing world (Dubberly & Pangaro, n.d.; “Making Sense of Today’s Tech World,” 2018).

Design can also make the changes of the future and their benefits and challenges visible to the masses so that we may all weigh in to how technology is going to shape the human condition. We need to predict the changes technology will bring and design for them.

The ramifications of technology on the human condition and culture are mired in contradictions such that attempts to marshal it into positive and negative are challenging. This section will examine design practices today and how they will be redundant or relevant in the future and attempt to understand the sociocultural changes brought about by technology that influence society and behaviour and therefore, Design.

1. Technology, People and Society

1.1 Hyperreality

Hyperreality is a condition in technologically advanced postmodern societies where the distinction between reality and fiction is blurred. Facts and figures, ie, reality, loses its weight against the influx of digital narrative that renders the spectacle being presented, like news or elections, more real than actual events. This means that public perception is not based on actually but its distorted portrayal.

In India, the 2019 Balakot airstrike served to solidify narrative and woo voters as opposed to long term diplomatic solutions. As of January 2019, social media, news channels, journalists and political leaders offer multiple, contending narratives such that ground reality is often irrelevant. Landmark news events one day are replaced by new distractions the next. Illustrations, cartoons, films, social media serve often serve as instruments of propaganda. This confused sense of reality manifests itself in dichotomies like the worship of a “Bharat Mata” (India as Goddess and Mother) and the high rates of gruesome crimes against women (Kamatham, 2019).

This is not particular to India alone. We have reached an age where symbols have replaced
facts. In the United States, Donald Trump’s showman, reality TV star persona and the name “trump”, often put in the forefront a powerful businessman, completely eclipsing whether he is a responsible leader (Albrecht, 2018).

1.2 Social Cooling
Edward Snowden revealed that the National Security Agency (NSA) collects data from internet companies such as Google, Apple, Facebook, Microsoft and others (Sottek and Kopfstein, 2013). With increasing online surveillance, our actions are monitored, measured, bought and sold. Studying an individual’s internet usage, social media activity, purchases, financial information, hobbies allow systems to predict the individual’s age, income, beliefs, friends etc and some systems, and countries are using this information to assign people a “Social Score”. (Schep, n.d.).
Social Cooling is a long term phenomenon that occurs in a reputation based economy which results in a culture of conformity characterised by self censorship, an aversion to risk taking, and rigid social structures (Schep, n.d.)

This kind of surveillance and persuasion can be used by authorities to pressure citizens into obeying expectations. Invasive and authoritative models of governance have historically limited the scope for healthy discussion, debate and creativity. (Williams, 2018)

1.3 Identity Formation

A capitalist society necessitates the rapid assumption and shedding of identities for consumption. The media and the internet cause this process of rapid consumption to accelerate through a culture of fragmented replication, reproduction and reinforcement of listicles, clickbait, memes etc. The images we see are often “quotational work” that appropriate information from various sources. Identification in this scenario is harder and our attention spans shorter. This frenzy of information sharing is linked to identity formation and those of us with weak egos fall into this pattern with relative ease. The identities we form through such consumption can often lack depth and are often fragile (Peretti, n.d.).

1.4 Accountability and Negative Behaviour

Initially the term “troll” was used to describe people who were part of an internet subculture based on playful needling. Initially harmless, we saw the emergence of far right, extremist groups out of this pool of internet ‘trolls’ on ‘4chan’ somewhere between 2008 to 2012. Some of the early internet ‘trolls’, include Andrew Anglin, publisher of The Daily Stormer, who achieved international attention when in 2016, he declared “Hail Trump” in a speech at Washington, D.C., and received Nazi salutes from his audience. As compared to pamphlets, radio, newsletters, and personal interaction, Anglin’s reach via the internet is staggering (O’Brien, 2017). The pace of sharing information is sped up further with ‘likes’ and ‘shares’, where people engage with an individual piece of text or image and not the larger context. Engaging with content, even to criticise it, gives information momentum so a
A lot of damage is done inadvertently through flattening of the context via technological affordances that amplify harmful behaviour. (Phillips, 2019)

Design Exhortation -

Much of the negative behaviour we see online, by individuals and by organisations, stems from the way designers and business owners strategise. Dark Patterns are interactions designed to mislead users. This is not sloppy design but stems from ill intent. With more of the world getting online, designers are increasingly responsible for how people experience the web. UX designer Harry Brignull, has been cataloging dark patterns since 2010 on DarkPatterns.org. Examples of these include ‘Privacy Zuckering’ where users are tricked into publicly sharing more information about themselves than intended. (Brignull, n.d.,)

Should designers perhaps, like lawyers and doctors, require legal licenses to practice? While this damages the democratic nature of the profession, it may help hold designers accountable. We could begin with ethics becoming a part of the design curriculum but more pressingly, designers need to start openly discussing their social responsibilities.

2. Technology, Accessibility and Knowledge sharing

Design packages new technology everyday, constantly improving the experience. Not only that, design can improve accessibility for a wide range of audience. Simple things like not using only colour to convey critical information, for example at traffic signals, have the potential to improve daily living.

Today the internet shapes us and everything around us. Initially a highly decentralised platform to discover new connections, interests and to share information, today a handful of companies control how we see and share information. Surveillance has emerged as the new business model for internet companies. Initially the Internet was the great equaliser, created with the vision of a truly equal, connected platform, free of the pressures of society. Without the expense of television, radio, newspapers, the internet made communication almost costless. It offered the possibility of an equal society (Kesvani, n.d.).

The internet has however failed this initial promise. Digital literacy is now essential to being employable and there is a gap being created. In under developed countries, women are 33% less likely than men to use the internet and in low and middle income countries, this gap is 26%. Reasons for this include cost, cultural factors, privacy concerns and time constraints (Leusse and Plou, n.d.).

It would however be remiss not to acknowledge the potential online learning has in providing equality in education and opportunity. Progress in this sphere has however been limited due to lack of incentive for commercial institutions and the possible threat to job security of academicians (Klain, 2015).

We also find technology facilitating the relationship between creators and their audience as they engage directly through the internet, making Art and information more accessible. We also see this in how the arts are engaging more audience through technology in public spaces (Ricci, 2018; Katz, 2018).
As of June 30, 2019, the United States saw 1204 website accessibility lawsuits filed in federal courts since January with a projected total of 2408 by the year end (Shaw, 2020). This is despite the States being and a world leader where designers have easy access to the Web Content Accessibility Guidelines with most citizens having internet access. The World Wide Web Consortium (W3C) makes many simple design suggestions (such as optimal colour contrast ratios, keyboard navigation support etc) and implementing commonly used assistive technologies (like speech recognition tools, screen magnifiers etc) (Henry and McGee, n.d.). It is also important to understand that when content and objects are designed to support disability, they also become more accessible for regularly abled persons. Everyone is disabled sometimes, whether through a temporary injury or being limited by multitasking (such as one arm being occupied with carrying a toddler or carrying a phone in one hand).

Designing for accessibility however, does not only mean reaching people with disabilities but also people with different cultural backgrounds and those in remote regions. For example, understanding that some writing systems like Japanese and Korean may require vertical text support. In Japan check marks may need to be converted to circles, which is their symbol for correct (“INTERNATIONALIZATION”, n.d).

3. Technology and Bias

The algorithms used to predict information through gathered data are not always accurate, and can perpetuate biases. The term “Mathwashing” describes the phenomenon of using “math terms (algorithm, model, etc.) to paper over a more subjective reality” (Wood, 2016). According to Olga Russakovsky, assistant professor in the Department of Computer Science at Princeton University, bias in AI has three root causes - i) Bias in the data being collected ie, overrepresentation of some categories and less of others. ii) The algorithms themselves as they tend to amplify bias in systems. iii) Human Bias ie, prejudices of the people collecting data (Smith, 2020).

Design Exhortation-

The automotive design and development industry is dominated by men and as a result in the 1960s, crash tests were done with dummies modelled after the average male and seat-belts were designed for them, making cars 47% more unsafe for women, particularly pregnant women. 2011 was the first time a female crash test dummy was used. Now with self driving cars, if voice recognition does not recognise every race and gender as human, it can have dangerous consequences (Reiley, 2016). Organisations and Designers must understand the potential of how dire the consequences of bias in technology can be. Furthermore, design and development teams must be diverse.

4. Technology and Ethics

Smartphones use the same neural pathways as drugs and gambling to hook people. (Andrew-Gee, 2018). There is an urgent requirement to regulate and monitor the
development and application of technology. While there are government and private bodies working on this and there are various guidelines for how and where ethics should be applied in technology, what is crucially missing is public participation (Brown, 2015). Till the larger public is involved, governments will not have enough incentive to ensure a humane approach to technological development and application. For the larger public to get involved, just disseminating information may not be enough. People often do not rely on information to form opinions but on assumptions and on opinions of others, very often loud political groups (Baron, 2019).

For educating the creators, liberal arts, study of ethics and philosophy should perhaps be a formal part of curriculum. Self-driving cars for example are already grappling with the dilemma of pedestrian life vs passenger. Education should aim to holistically develop human potential and advancement in technology should aim to make life better, not merely more convenient.

Design Exhortation-

Most decisions that influence design, ie, the technical and commercial aspects are planned long before designers get involved. Designers are systems thinkers and communicators and need to design more than just screens. They need to design policy. Ethical implications should come as a precursor to technological application, wherein ethics assist the design and development of technology and do not manifest after the technology is implemented.

Independent developers are working on innovations to change the infrastructure of the web through decentralised web apps such as Graphite docs, an encrypted alternative to Google Docs. Right now these applications are not as intuitive or polished as their counterparts but should designers get involved, they could be.

Designers can also create awareness and disseminate information to educate the general public and initiate dialogue. In the wave of recent protests in India against the contentious “Citizenship Amendment Act”, Indian designers are chronicling the movement and educating the general public by offering easily consumable information that challenges the state sponsored narrative, and are creating a movement of political consciousness (Raghav, 2020).

5. Technology and Opportunity

We examined how technological literacy and bias are creating gaps thereby unfairly stifling opportunities for some. We now consider whether AI will make life more comfortable or reduce work opportunities creating a widespread job crisis. On one hand we have seen jobs becoming redundant such as travel agencies, elevator operators etc but we have also seen creation of new jobs like app developers, social media managers, data scientists and others.

Daugherty and Jim Wilson, of Accenture Research have bifurcated jobs into trainers and explainers wherein the former train AI systems and the latter function as liaisons between machines and human supervisors. AI can potentially emerge as a tool to assist better
performance by people and assist with unfilled jobs such as the shortage of truck drivers in the US where automation may offer better productivity and lifestyles ("AI and the Future of Work", n.d.).

However, not everyone sees AI as a positive tool to augment jobs. The Forrester report (Future of Work) predicts job losses of 29% by 2030 with only 13% job creation to compensate. To prepare for this scenario, the report makes recommendations in government policy, economic planning, business planning, leadership planning and individual planning ("Future of Work", n.d.).

Design Exhortation-

Brands like Airbnb and Uber do not offer any new products at all but just good design. There are multiple companies offering the same service and technology. Design is the key differentiator. Consumers today do not have the patience to decode and understand how something works. It has to be intuitive. Design and technology will work together, abolishing constraints of effort, mechanics, space and time.

Design is about a holistic experience and to create such an experience, Designers will need to understand the function and context, ie, culture, which includes aesthetics, material, narrative, language and the interaction.

We can expect to see tools to make these challenges easier and integrate design, software and hardware knowledge. AI could potentially help designers impartially evaluate the quality and impact of their work. We will also have access to more information yet as Big Data and personalised experiences continue to grow in importance. We will also see greater diversity as more women and people from different cultural and ethnic backgrounds join design teams. This will be essential to understanding context.

6. Technology and Sustainability

In recent years innovation has turned to sustainability as we tackle depleting natural resources, pollution, disasters, energy and water shortage. With mounting public pressure and actions being taken through regulations and policy makers, organisations will now need to tackle economic sustainability, societal sustainability, and environmental sustainability. There is evidence that the sixth wave of innovation is in Sustainability (Silva and Serio, 2016).

Design Exhortation-

Everything that is designed is created that way to be consumed, generally at the cost of our environment, culture, society and well being. Most personal electronics are packed with environmentally hazardous chemicals and minerals like mercury, lead, nickel, cadmium, phthalates, and others (Sheesley, 2008). In design making a product sustainable is often tacked on to the brief as an after thought for pleasing consumers, for the reputation of the organisation or to follow regulations. This is gradually changing as we move from a cure
approach to a prevention approach. This expands the role of Designers wherein they become the link between production and society, enabling more sustainable lifestyles as we move from designing just products to designing entire systems. Design for Sustainability (D4S) is a system design approach beyond Life cycle Accessibility (LCA) and Cradle 2 Cradle (C2C) that embraces the best practices to meet environmental, social and economic needs. This means preserving natural resources, protecting local communities while meeting economic goals, via the ‘4P’ approach, ie, Product, Planet, People, Profit (Diehl and Marcel, 2008).

7. The Coevolution of the Artificial and the Natural

A Transhuman is a human being who has transcended boundaries of human intellect and physiology through technology. Transhumanist thinkers also postulate that someday humans may be able to become ‘Posthuman’, ie, beings evolved from humans through technology but vastly more capable and radically different.

Raymond Kurzweil, Google’s Director of Engineering, predicts that “By 2029, computers will have human-level intelligence”. According to Kurzweil, the process towards ‘Technological Singularity’, a stage at which machines surpass human intelligence, has already begun.

Kurzweil has announced, “That leads to computers having human intelligence, our putting them inside our brains, connecting them to the cloud, expanding who we are. Today, that’s not just a future scenario. It’s here, in part, and it’s going to accelerate.” Since the 1990s, Kurzweil has made 147 predictions which he claims have had an 86% accuracy rate (Reedy, 2017)

There are also strong concerns that this evolution in technology may not happen in tandem with human existence, ie, machines may surpass us thereby threatening human life and dominance. Bill Joy postulates that technology will either overtake or overrun humanity itself or that the intelligent machines will be controlled by an elite few where the masses will lose value, be reduced to the status of animals (Joy, 2004).

Design Exhortation-

Design Fiction is a discipline and a method of postulating the ethical, social and cultural concerns of emerging and future technologies through design and storytelling. It often employs diegetic prototypes to convey how a piece of technology could function within the fabric of our world. The term was first used by Bruce Sterling in 2015 who elaborated on how such a model could “suspend disbelief about change” (Bosch, 2012)

Emerging technologies offer great benefits but pose serious risks with great potential for abuse and their potential to replicate which makes them especially problematic given that we also do not fully understand the technologies themselves and their future evolution. (Joy, 2004) . There are independent groups and individuals working formally in the field, such as
the Near Future Laboratory, that create conceptual and tangible prototypes, models, and research to explore the future ("Near Future Laboratory", n.d.).

Design fiction is a young but promising discipline that can help us visualise the impact and function of existing and speculative technology in our lives and society. It does not address design problems but rather creates dialogue around them. The field is still in need of formal models of prototyping, critique and evaluation (Lindley, 2014).

In Conclusion

"The future is no longer regarded as predestined...It is now seen as the result of the decisions, discoveries, and efforts that we make today. The future does not exist, but a limitless number of possible futures can be created.”

(Bell, et al., 2013, p. 5)

Design can help us improve how we apply technology to everyday life today and help us both visualise and create better models for technological application in society in the future. On one hand the democratic nature of the field allows for many explorations but on the other, designers are rarely held accountable for many of the problems related to the consumption of technology today. We crucially need regulations and policy to determine the course of technological exploration and we need better models to assess the roles of designers, their responsibilities and their potential in designing our lives in the present and the future.

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Designing Somatic Play for Digital Natives through a Body-centric Design Process

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Abstract | Designing interactive toys for digital natives is an emerging field that embraces new ways of integrating digital technologies with physical objects to create tangible whole-body interactions. This paper presents Wearable Play, a project that followed a design process inspired by human body movements to develop age-appropriate “somatic play” experiences for children. It is a soft interactive toy WORM-E and its five potential interaction scenarios that engage children in bodily activities for more self-awareness and social interaction. Reflections on the design process address the importance of a body-centric design approach, the difficulties that appear when integrating electronics into textiles, and the challenges of working on a physical design in a remote team.

KEYWORDS | E-TEXTILES, INTERACTION DESIGN, INTERACTIVE TOYS, PLAY, SOMA-DESIGN
1. Introduction

“Digital natives” who are born into the digitally augmented world, have an experience of the material culture, in which the connection between them and the world around them is largely mediated through digital devices (Prensky, 2001). Most of the time, children interact with the devices that allow them to play, learn, and communicate through a screen. Some scholars argue that this can have consequences and effects on the wellbeing of children, ranging from psychological, physical to social implications (Turkle, 2015; Kardaras, 2016). However, children’s digital technology use is a reality which should be handled delicately and wisely (Prensky, 2012), rather than blindly accepted or totally rejected. New ways of creating harmony between what happens in the physical and the digital sphere can enhance the wellbeing of digital natives by weaving the digital technologies “into the fabric of everyday life” (Weiser, 1991, p.94). Technology embedded toys (e.g. smart toys, connected toys, etc.) help children explore the physical world while offering a variety of input and diverse output to create interactive and connected play. This potentially extends the interaction from finger-tips on a screen to a whole-body contact with objects, spaces and peers or parents. As it is an emerging field, it also brings the necessity to refine principles, attitudes, tools and methods for designers.

This paper analyses the insights gained from Wearable Play project funded by WORTH Partnership Project. Within one year, a team of e-textile designer-researchers aimed at creating an interactive soft toy – WORM-E that would provide children with whole-body interaction and “somatic play” experiences. The project connects the safe and comforting character of textiles with the dynamic properties of digital technologies to create synergies between the screen-based and physical play. The work follows an experimental design approach combining elements from body-centric design with participatory design methods integrating the users in early phases of the project through exploration of mock-ups and prototypes. The paper addresses the design process inspired by body-centric experiments and describes how this method gives rise to “somatic play” experiences for children. Moreover, it contributes to the discussion about how designers can incorporate electronics into toys while considering issues such as safety, privacy and sustainability.

2. Background

2.1 Children in Digitally Augmented World

Smartphones act as entry level devices through which children make their first contact with the digital sphere by watching videos, playing games, participating in video calls, etc. (Chaudron et al., 2015). While smartphones allow us to connect with others digitally, they often isolate the child from his/her own surroundings and from possible physical interactions with other children or adults in the same space (Turkle, 2015). The American
Association of Paediatrics-AAP (2016) suggests the avoidance of any screen contact for toddlers under 18 months and recommends maximum one-hour screen-based play per day for 1-5 years-old children. In Germany, the screen time is recommended to be maximum 30 minutes for pre-school children (4-6 years), while physical activity should be minimum 180 minutes per day (Rütten & Pfeifer, 2016). Moreover, Harris et al. (2015) mention that breaks with stretching body exercises could be helpful for children while using digital devices.

The need and desire of keeping the body physically active while playing a video game gives rise to new type of interfaces – so-called “bodily interfaces” – in which the body plays an active role in controlling the virtual game (Parisi, 2011). These interfaces can expand the game into physical space by involving the whole body: through hand-held devices complemented with motion sensors (Nintendo, 2020); hands-free systems with motion-tracking cameras (Xbox 360, KinectTM); or interactive mats (DDRGame, 2020). Although these games aim at making people move, they still rely on a strong mediation of visual outputs and this requires a continuous eye contact with the screen. This type of interaction modalities creates “a new set of bodily habits” (Parisi, 2011), which sometimes do not follow natural body movements, but require adaptation.

Besides these examples, there are also smart toys embedded with sensors and actuators that respond with various sensorial outputs such as vibration, sound, etc. without the need of a screen. For instance, the Moff band (Moff, 2016) is a wearable smart toy that turns motion into sound to augment everyday objects by giving them a voice. OCTOBO (Thinker-Thinker, 2019) is a smart companion for storytelling activities, reading physical tokens to create new stimuli for reading a story. Besides smart toys, there is an emerging field of the Internet-connected toys. In the market, there are different types of connected toys providing communication over distance by tactile and visual signals (VaiKai, 2016), informing children about their curiosities to make learning more playful (CogniToys, 2018), or chatting with them as companions (Mattel, 2017).

2.2 E-textile Toys

From early ages, children seek comfort in textile objects, for example, having a preferred stuffed toy or blanket (Winnicott, 1953). This instinctive behaviour continues as the child grows, however materials of toys become harder and colder, especially when smartphones enter in the play activities. The field of e-textiles (electronic textiles) shows a great potential in creating new tangible and bodily interfaces for children. E-textiles embody soft and sensorial characteristics that are augmented with responsive features of electronics. Conductive yarns can be knitted, woven, or combined with textiles through other crafting techniques to create soft sensors and actuators. Being soft and flexible, e-textiles can be worn on the body as a garment, hand-held as a stuffed toy, or applied on surfaces, such as a carpet. E-textiles can provide a whole-body experience, inviting the user to touch and move intuitively (Honauer et al., 2019).
There are some examples of e-textile toys for children merging electronics and textiles to create new experiences and play modalities. They enhance children’s physical connection with their own body, the surroundings and with others. Spookies are one of the first interactive toys that use smart textiles as soft interfaces providing free play with various input and output possibilities (Berglin, 2005). BabyTango is an e-textile stuffed toy integrated with embroidered sensors and soft circuits to support empathy by embodied play for toddlers (Berzowska et al., 2019). Besides, Pouta and Mikkonen (2019) presented an interactive hand puppet with a woven touch sensitive textile that creates an interactive gaming experience between a child and an adult by detecting the wearer’s hand movements and the touch of the viewer. Mazi is another e-textile toy that aims at providing sensorial regulation and collaboration for children with autism in a playful way (Nonnis & Bryan-Kinns, 2019). Children with various spectrums of alertness sensitivities can also be supported with e-textile toys created by design students as part of their social design course (Kuusk & Nimkulrat, 2018, 2019). Within the Rhyme project, the researchers developed creature-like, large-scale, interactive soft objects providing a whole-body interaction through audio, visual and haptic feedback to enhance the users’ wellbeing (Stensæth, 2014). Only few of the e-textile examples are brought to the mass market, as many details need to be addressed first (e.g. production at scale and marketing).

3. Wearable Play

Wearable Play combines contemporary, digital technologies with textiles to create new “somatic play” experiences for children. The authors attempt to design with, through, and for the body (Tomico & Wilde, 2016). They take a Research through Design approach (Frayling, 1993) by learning from designing, making, as well as testing prototypes on their own and observing users in interaction with the resulting prototypes. In doing so, the authors involve children and adults at various stages of the design process assigning them roles, ranging from users and testers to informants (Druin, 2002). The project involves two age groups of children: the preoperational (2 to 7-year olds) and the concrete operational stage (7 to 11-year olds) (Piaget, 1964). The whole project was conducted in a remote design team with members situated in three different countries (Italy, Germany and Estonia).

3.1 Multi-Method Design Process

The Wearable Play project follows a multi-method design process, combining body-centric design and participatory design methods to understand respective needs of the target group, and to design for their body movement. The project consists of three phases: 1) requirements analysis and problem definition, 2) design of the prototype and its interaction modalities, 3) production of the prototype with the integration of textiles and technology.
3.2. Requirements Analysis and Problem Definition

Before the official start of the project, two of the authors initiated a workshop “Children, Interaction Design, and Soft Materials” at Unibz, Faculty of Design and Art, in Bolzano, Italy. They conducted a brainstorming session with design students participating in the workshop. It was followed by a body-storming activity introducing an embodied ideation process based on role-playing (pretending to act like a child) and a case study mapping of children toys embedded with technology. Based on the outputs of the workshop, a critical reflection was made to cluster topics and issues around digital natives. For example, raising awareness for social reality and their own body, and reducing screen time and smartphone usage were some of the issues which emerged from this reflection session.

After defining the design space, the authors started sketching initial design ideas based on the three main pillars: design for children, design for bodily and social interaction, and design with e-textile materials. This collaborative brainstorming session opened the authors’ imaginations and helped to discuss the users’ needs.

Next to idea generation, the authors conducted direct observation in children’s natural environments. All authors did an observation session lasting approximately one hour. The sessions were conducted in three remote geographical locations (Estonia, Italy, and Germany) in a playground, skate park, and kindergarten. That enabled the authors to observe how children of different ages (3-15 years) play and move. Across age and country, the observation of the children’s movement in free-play revealed that children usually play together in groups, they explore the space with full-body and highly active motions. An individual game only lasts a few minutes, and playing is mostly driven by the parents, children’s fantasy and objects at hand.

3.3. The Design of the Prototype with Its Interaction Modalities

After analysing the observations and the results of the first ideation session, the authors remotely created low-fidelity prototypes based on agreed ideas to test them by themselves, through taking a first person-perspective to design for the body (Höök et al., 2018). A big stuffed toy, a hug-inviting soft object, a worm-like soft object and a stretchable textile tube were developed by the authors (see Figure 1). The try-out sessions were filmed and photographed for exchange of the lived experience between the three authors.

Figure 1. First prototypes and body-based explorations of them.
The worm-shape object could be worn around the body, wrapped around multiple persons and allowed for both active and calming activities. Hence, it was selected as the most suitable form for further prototyping. In this stage, the prototyping was meant to investigate the look and feel while exploring different ways of interaction, therefore there was no technology integrated yet in them. After developing the low-fidelity prototypes, each author remotely created a worm-like object as a probe to test with children and a professional dancer, since it was difficult to fully immerse being a child by the authors. Dancers are experts for movement because they are trained in body tension, dance motions, and body postures that usually go beyond what laypersons can do with their bodies. Therefore, a dancer was involved by one author to explore more possibilities of body movements (Figure 2, on the left). The two other authors observed children (3-6 years old) playing with the probe in a home and kindergarten environment (Figure 2, middle and right). While the children were asked to freely interact and play with the probe, the instruction for the dancer was to improvise with the given shape. While freely playing and improvising, our young and adult test users figured out a lot of interesting movements that the authors later used in order to develop the interaction scenarios as described in section 4.

Based on the observations done in the sessions of free play with the probe, the authors generated movement cards illustrating five different play possibilities (Figure 3). In a further testing, these cards were given to children together with the probe to see if the cards could inspire the play (Figure 4, on the left). The evaluation with 4 to 7 years old children revealed that the users were very interested in the movement cards. They could easily enact the tasks shown on the cards and developed their play beyond the inspiration by the cards. Moreover, the cards were tested by two design students that found the cards useful for some initial triggers to play, but after a while they did not follow the cards and rather invented new game modalities with the probe (Figure 4, on the right). These cards later became a part of the application which the authors explain in the interaction scenarios (Figure 6).
Designing Somatic Play for Digital Natives through a body-centric design process

3.4. Production of the Prototype with the Integration of Textiles and Technology

The authors decided to use Near Field Communication (NFC) technology for enabling communication between the soft toy and the smartphone or tablet used by a child. The NFC tags were the preferred choice because these computational elements are soft, tiny, flexible, robust, easy to integrate into textile objects, battery-free, and compatible with all NFC-ready devices. For a more advanced version, LEDs could be embedded onto the NFC tags. Additionally, tactile feedback would enhance the interaction with haptic sensations. For that, small vibration motors were chosen because they can be controlled with an e-textile microcontroller, such as Lilypad or Flora and their power consumption is manageable with smaller batteries. To enhance the tactile sensation, the cover of the final prototype was constructed with different textile segments that have various tactile properties with different surface structures (Figure 5).
4. Interaction Scenarios with WORM-E
The prototype of WORM-E consists of a 2-meter-long stuffed toy embedded with NFC tags. The tags inserted into the textile cover turn the toy into a key to activate various content elements shown on an application for open-ended somatic play experiences. The toy aims to engage children (4-11 years old) into whole-body play after or during continual usage of a smartphone or other screen devices.

The WORM-E application friendly interrupts the user and prompts to stop looking at the screen after a certain time (approx. 30 minutes, but can be modified based on the parents’ decision). It invites the user to try a game with WORM-E. The only way to know more about the game is to bring the WORM-E close to the smartphone in order to access the content by scanning the NFC tags on the toy (shown in the interaction scenario in Figure 6). Then, a predetermined activity is proposed. The activities described below are enhanced by actuation components (LEDs and vibration motors) embedded into the prototype using e-textile techniques. All interaction scenarios are derived from observations and tests with users addressed above.
4.1 Balancing

The body-balancing activity looks like walking on a rope, asking the child to walk on the soft toy while following the vibro-tactile feedback on his/her feet (Figure 7). The activity requires concentration and a good sense of one’s body. The tactile stimuli delivered by the vibration motors within the toy guides the balancing steps. The child is invited to feel and follow the buzzing sensation with her/his feet. Every time the vibration pattern varies from the previous experience through speed, direction and intensity. The attention of the child is brought to the sensation felt by the feet.

4.2 Skipping Rope

In this activity, the soft toy is used as a swinging rope to jump over. The activity stimulates the children, alerting and exciting them (Figure 8). It can be played by 2 or 3 children as it
exercises teamwork and trusting others. In the case of two children, the phone should be placed on the floor in the mid distance between both children, and the NFC tag acts as a counter to keep track on the number of swings. In the case of 3 children, there is a light pulsing on both ends of the worm to indicate the speed of skipping. The game has various levels; for example, light can indicate when to jump with one or both legs.

Figure 8. Children and adults exploring the low-fi prototype, that lead to the skipping rope activity.

4.3 Tug of War

Tug of war makes children pull the toy from two ends (Figure 9). It stimulates the players, requires strength, might create some tension and invites for teamwork as well as friendly competition. The smartphone is on the ground under the middle of the toy, children at both ends grab the toy. The players pull the ends of the toy when the game has started while trying to make the “opposite” team move forward from where they stand. The users need to let the toy down after each “battle” in order to collect points though NFC reading with the phone in the middle, LEDs in the read segments light up shortly to indicate a successful read.

Figure 9. Children and adults exploring the low-fi prototype, that lead to the tug of war activity.

4.4 Embracing
In this activity, WORM-E “hugs” the user while sending vibro-tactile stimuli (Figure 10). It aims to calm the child and allow them to look inward, relax and focus on their own body and soul. The soft toy is wrapped around the body of the user in a comfortable position. While doing this activity, the phone can play an audiobook or sleeping song, while the LEDs are lit up in a dimmed manner.

Figure 10. Children and adults exploring the low-fi prototype, that lead to the embracing activity.

4.5 Swirling

The user spins around having one end of WORM-E attached to their shoulder (Figure 11). The toy follows the player. This activity stimulates and excites the user. It helps them to concentrate and look for body balance. The light embedded into one end of the toy lights up based on the growing speed in brighter colours. This motivates the player to swirl faster and faster.

Figure 11. Children and adults exploring the low-fi prototype, that lead to the swirling activity.

5. Discussion and Conclusion

The integration of digital technologies into soft objects opens new ways of play and allows digital natives to spend less time in front of the screen, to engage more with their physical
environment and with other children. To achieve this, the technology should not be the main starting point for the design process, but rather it should be an enabler for new interaction modalities that are driven by the user’s body. Designers can use the soma-aesthetic design approach which makes the designers learn from their bodies (Höök, 2018). Ideating with the body allows “designers to design for the senses from the senses, opening the door for multisensory interactive qualities and complex interrelations between the senses” (Tomico & Wilde, 2016, p.13). In the Wearable Play project, the authors combined methods from soma-aesthetic design with participatory design methods to understand the wide spectrum of experiences available between the designed object and the moving body. Experiencing objects from a first-person perspective gave more embodied information and provided a more reflective view than observing users or conducting a brainstorming. Additionally, the authors could gain more insights into bodily motions through involving a professional dancer. That all allowed to combine the first-person experience with the analysis of the users and the improvisation of the dancer.

Over the course of the project, the authors discussed how to seamlessly and sustainably integrate textiles with technology. Taking advantage of craft techniques allows for quick prototyping, but places some constraints for later production possibilities. The use of e-textile brings major environmental concerns to the discussion (Köhler, 2013; Velden et al., 2015; Veske et al., 2019). One of them is the use of energy and how to ensure the power source to be environmentally friendly and safe for the users. One of the reasons to use NFC was driven by the fact that it functions independently from an additional power source. However, this shortly influenced the ideation process to be more technology-driven, focusing on what NFC could do, rather than the bodily interaction. Moreover, technology inside a textile prototype rises also the question of washing and robustness. The final object was designed modularly, so technological components can be temporarily removed for cleaning and maintenance. Further sturdiness and recyclability issues need to be solved once the WORM-E prototype has been thoroughly tested.

Providing a smartphone application and collecting user data raises important issues about privacy and safety. The Designing for Children Guide (D4CR, 2018) considers the risk of misuse of data as one of the ten principles to keep in mind when designing digital products and services for children. On one hand these data are helpful, so the parents can observe children’s activity. On the other hand, this demands great attention to make sure the data is not misused or does not get into wrong hands. Also, it puts the responsibility to the parents, so they need to be informed sufficiently about different possible consequences. Here, designers can provide ethically valid solutions to inform and empower the users.

The authors experienced benefits and difficulties of working in three physically different places and using different communication channels to be in contact. This challenged them to present the concepts and ideas clearly, in a way that they could be “experienced” over distance, which at the same time created a good trace of documentation of the project development along the way. Additionally, the geographical distribution allowed the authors to involve expertise and participants from various locations extending their network and
Designing Somatic Play for Digital Natives through a body-centric design process

reach. Here, the importance of the prototypes, as the only physical touchpoint, became crucial to communicate the project, and the authors all constructed the same shape remotely in the exploration phase. Later, they distributed tasks (product design, hardware design, and application design) and sent all the results to one of the authors who put them together.

In the future, the authors plan to do elaborated user tests with children of the respective age group. Possible data collection methods are observation, interviews, and diary keeping. Tests are planned under semi-controlled conditions in the children’s natural environment while the researchers are present (e.g. in a kindergarten or public playground). For a longer test period, the final prototypes will be handed over to be used as probes for individual tests in a child’s home. Soma-based methods are not only useful to design interactions and engage with materials or digital technologies, they are likewise important for evaluating prototypes and existing design solutions (Höök, 2018). That is why, the authors plan to not only test their final prototype with the target users, but also to experience the final prototype with their own bodies and to feel the individual psychological and physical sensation triggered by the soft toy.

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Designing Somatic Play for Digital Natives through a body-centric design process

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Designing unpredictable futures.

An anthropological perspective on the algorithmical prediction of human behaviour

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Abstract | In this paper, we propose a cultural interpretation of the role of designers who work with data in Global North society, drawing on a comparative anthropological method. We trace connections between them and those who master technology in other societies, i.e. blacksmiths in West Africa, in order to interrogate the cultural meaning of the practice of pattern recognition. There are many concerns (mainly ethical and epistemic) and an increasingly lively debate around the growing role played by data-driven objects, infrastructures and systems in our daily life. The comparison that we propose draws on but also adds to this debate, emphasizing the socio-cultural risks and opening to reflections that may avoid these. It calls into question the emerging feature of aliveness of technology and the scientific and socio-cultural consequences that come with it.

KEYWORDS | BIG DATA, ALGORITHMS, FUTURE, WILDERNESS, ANTHROPOLOGY
1. Introduction

This paper proposes a cultural interpretation of the role of designers who work with big data and algorithms for the prediction of users’ behaviours, ideas and tastes. To this aim, we will adopt a comparative lens, which will trace connections between global North designers and West African blacksmiths.

While Mande blacksmiths and global North data designers are quite fairly two different groups in many aspects, both are masters of technology. By naming smithery as a technology, we join efforts within history and the social sciences to multiply technological imagination about what techne can be when the material meets the social (see Olson, 2018, p. 229, note 4). Our aim in this paper is to offer insights to data designers to think otherwise their role in dealing with technology.

We found the comparison between these two very different groups particularly propitious for two main reasons. First, both groups aim to master apparently invisible and wild forces through their technology. Second, in both cases what they are dealing with (data or spirits) seems alive, wild and invisible.

There are many concerns (mainly ethical and epistemic) and an increasingly lively debate around the growing role taken on by data-driven objects, infrastructures and systems in our daily life. The comparison that we propose will draw on but also add to this debate, emphasizing also the socio-cultural risks and opening to reflections that may avoid these.

2. Methodology

The comparative approach is at the core of the cultural anthropology research method. Clyde Kluckhohn has famously defined cultural anthropology as the “longest way round”, which happens to be the shortest way back home (Kluckhohn, 1949, p. 20). Through this apparent paradox he intended that one should explore different ways of approaching and framing the world, in order to grasp the limits and potentialities of his/her own ways of thinking and doing. More recently, Tim Ingold has defined the anthropological attitude as a “constant awareness of alternative ways of being, and of the ever-present possibility of ‘flipping’ from one to the other” (2011, p. 239). This constitutes a “sideway glance”.

Wherever we are, and whatever we may be doing, we are always aware that things might be done differently” (2011, p. 239). From this perspective, cultural difference represents a fruitful repertoire of alternatives, which expands the imagination and helps to encompass the constraints of one’s own cultural world. In a similar vein, throughout his career, Francesco Remotti (2014) has made a strong argument for the adoption of a transversal gaze in anthropological research. In his view, intercultural comparison has the fundamental function of offering a critical standpoint from which it is possible to scrutinize one’s own society. Only when researchers distance themselves from their hic et nunc and craft - as Remotti (2014) would put it - “untimely spaces [spazi di inattualità]”, new theoretical perspectives to grasp and change the status quo can emerge. According to this methodological framework, legitimate cultural comparisons do not happen merely between geographically close and historically connected societies; they also occur between societies
that are distant in time and space, if they allow for “illuminating connections” (Geertz, 1973, p. 56-57). It is in this vein that in this paper we take the “longest way round”, which goes across the Mande blacksmiths, to look at (and challenge) contemporary global North data designers’ culture (Pype, 2018, p. 5-6).

3. West African masters of technology: the Mande blacksmiths

Mande people are a linguistic group, made of several ethnic clusters (e.g. Banama, Malinke, Wasaluka, and Dyula people), who inhabit a region that includes part of Mali, Burkina Faso, Senegal, Gambia, Guinea, Sierra Leona, Liberia, Ivory Coast, and Ghana. Being a language, Mande offers a strong sense of belonging to the people who speak it, and the linguistic identification can exceed the ethnic one. Mande society is traditionally characterized by three fundamental divisions: the farmers, who were the nobles (horonw), the slaves, who were war prisoners (jonw), and the specialized professionals, called nyamakalaw, as nyama means “the energy for action” (McNaughton, 1993, p. 5).

Blacksmith men belonged to this latter social group, together with bards, praise-singers, entertainers, woodworkers, leatherworkers, and Muslim holy men. Even today, blacksmiths are associated by West Africans to these other specialists, revealing the fact that these masters of technology play a multifaceted social role. Their main job is to fabricate tools and artefacts. However, they work as healers, rainmakers, diviners and fortune tellers too. Thanks to their role as makers of amulets and other secret devices to protect oneself from disease, improve finances, and help in other social matters such as romance, they are acknowledged as able to mediate conflicts, arrange marriage and even to perform ritual roles in the circumcision of boys, transforming youth’s bodies from natural into cultural. Mande blacksmiths are recognized so powerful because it is thought they have a privileged relationship with the spiritual world, which imbues them with secret knowledge and skills. To master technology, in the Mande world, is to channel the wild powers of nature into cultural frames with the goal of improving the community both materially and spiritually. When Mande blacksmiths shape iron into tools, wood into masks and immature boys into Mande adults, they articulate spiritual, physical and social forces together, bringing movement and change into Mande society (McNaughton, 1993, p. 156).

Blacksmiths’ role as “articulators” between the visible and invisible world draws on the belief – widespread in African societies – that invisible spirits are wild but not necessarily dangerous (Geschiere, 1995). In their wilderness, spirits are neutral. The role of the blacksmiths is therefore key because they can master invisible and wild forces either for the good (i.e. to reinvigorate society) or for the bad (i.e. to break social bonds). By straddling the visible and the invisible world, blacksmiths should be able to domesticate the “wilderness” of the invisible to put it to work for human benefits. Their creations (being them tools, amulets, treatment, etc.) are not untamed wild nature but socialized assemblages of materiality and sociality, which, ideally, should follow and facilitate human needs (Pype, 2018, p. 8).
The imbrication of nature and culture embedded in blacksmiths’ technological artefacts makes these ambivalent products because they retain a symbolic link with the wilderness of spirits that even if not necessarily dangerous, has always something that escapes human grasp. The technology produced by blacksmiths is always open to the possibility to turn being evil or unexpected, even if momentarily its potential danger and polymorphism has been tamed. Mande people are aware that the technology produced by blacksmiths has always a link with a world which is beyond everyday life, potentially charged with an unsettling energy which is partly out of control (McNaughton, 1993, p. 149, 162).

Technology, in the Mande world, far from being something stabilized or something one can fully rely on, it is rather considered liminal, constantly overlapping the world of humans and non-humans, familiar and strange, beneficial and dangerous. Even if the “wild” energy of technology is tamed and channelled for human needs by blacksmiths, it always and necessarily maintains the potential for an autonomous agency, which escapes humans’ understanding and will. Mande people are thus mindful that blacksmiths technology has an original otherness that does not fully match their world, neither their wishes and needs. In light of that, blacksmiths - as producers of technology - are perceived as liminal and ambivalent too. As mediators between wilderness and culture, they tend to occupy a liminal position, being invested with salvific and dangerous power at the same time. They are simultaneously admired and feared, respected and contemned (McNaughton, 1993, p. 41, 160). Moreover, in the past (Ezra, 1989, p. 13), their power was also at the service of the rulers, sometimes with unjust and dominative ends. They fabricated the tools and weapons that rulers employed to control the people through taxes, military break-ins, and other kind of intrusions in everyday activities. This legacy is still alive in the Mande popular perception of the figure of blacksmiths, enhancing their ambiguity. People, indeed, are aware that blacksmiths could use their secret knowledge to weaken human society, instead of reinvigorating it. As they used to equip powerful rulers with their means of control, thus contributing to people’s disempowerment, in some respect they also are the target of resentment (Ezra, 1989, p. 13).

In the next section, we will analyse how Mande blacksmiths’ activity, role and recognition can be compared to global North data designers and inform what they do.

4. Data designers as masters of technology: comparative insights

4.1 Similarities – Data as spirits

Like West African blacksmiths, global North data designers are considered powerful for their capacity to create order out of the chaos of data. Data, for data designers, are what spirits are for Mande blacksmiths. In the digital era, data have become a new wild nature. The cultural imagination of data conceives them as raw material, which needs to be “harvested”, “mined”, “captured”, “hunted”, “mapped”, “extracted” and “analysed” by data scientists. This terminology, which is typical of both the scientists’ jargon and the ordinary talk, clearly
shows that in global North’s culture the world of big data is symbolically understood as a wild, pre-cultural realm that data scientists are able to tame and “cultivate”, making it intelligible (and thus sellable) for human needs (Zaloom, 2003; Weinberger, 2011). Google computer scientists played a pioneer role in this regard, since they firstly envisioned the possibility to make sense of the sheer amount of data produced by users, seeing them as “golden dust” (Zuboff, 2019, p. 68) and the “next natural resource” (Deutscher, 2013), rather than as useless “waste material”. Founded in 1998 by Stanford graduate students, Google was able to impose computer mediation to an increasing amount of human actions, thus producing new data on the users. Even though initially data were considered simply by-products and ignored as “waste”, engineers quickly understood that data could be aptly analysed as sensors of people’s behaviour. To this aim, they embarked in designing machine intelligence operations that transform raw material into algorithmic products, which could predict the behaviour of the users (Zuboff, 2019). This extra information has been used to improve services and users’ experience, offering them customized technologies that ideally are able to mirror what they think, feel, and like. For example, Facebook has recently launched Facebook dating, which is a service that makes suggestions to the users about people they might like, on the basis of their preferences, interests and other things they do online. The so called “like button”, firstly invented in 2005 by VIMEO, is at the core of this development, being part of an increasing number of networking services. In addition to Facebook, it has been integrated into Youtube, Twitter, Instagram, Tik Tok, Linkedin, and other social media alike. As a critical aspect of our present-day human interaction with computers, it provides data designers with a bulk of data on people’s opinions, tastes, and feelings regarding a wide range of aspects of their life, such as politics, employment, health, and education. In return of this information, data designers constantly adjust and refine their creations to better match users’ profiles. This work of entering into contact, mastering and disciplining the wilderness of data appears then similar to the one performed by Mande blacksmiths who have to master the wilderness of spirits. The technology produced by both data designers and blacksmiths through their work of domestication is put at the service of human needs.

4.2 Similarities – The aliveness of technology
As in the case of blacksmiths, the technology produced by data designers retains a connection with wilderness because it seems “alive”. Even if technology anyway needs humans to keep “living” and doing so properly (Pols, 2012), current technology and their spectacular performances (as smart services or algorithmic recommender systems) may give the impression to have their own intelligence and autonomy, thus being “alive” (MacKenzie & Munster, 2019). The “Internet of Things”, for example, has opened a new discourse in interaction design, putting into dialogue objects with people, both sentient entities. Designers have started to design quasi ‘living entities’ that can perceive us and “perceiving us perceiving” (Overbeeke, 2011). O’Sullivan and Igoe put into question how computers perceive humans, and proposed a change by shifting our focus from our own perception to the computer’s perception (O’Sullivan & Igoe, 2004). “Beyond human-centered design”
“post-human-centered design” (Forlano, 2017), “Xenodesign” (Schmeer, 2019) and “designed animism” (Laurel, 2008) are among the terms that are emerging. While this has opened a series of new ethical concerns, here we simply wish to point to how technology is increasingly perceived as having a life of its own. We expect that new technologies not only perform tasks, but also perceive and comfort us, that they recognize who we are and what we need, becoming customized. In this vein, technologies are not to be understood as mere tools anymore; they are rather “partners” with whom to exchange and have pleasant experiences. The fine line between alive and non-alive, the physical and the social, humans and other intelligent entities is undermined (Suchman, 2007).

4.3 Differences – How to manage the relation between spirits/data and humans

While so far we have highlighted elements of similarity (despite the many obvious contextual differences) between Mande blacksmiths and data designers, we now turn to analyse one crucial difference that distinguish them and has important scientific, social and cultural consequences. The technology produced by West African blacksmiths always retains a link with the wilderness of spirits: both users and blacksmiths are aware that technology is a transient product, deriving from a world which is beyond everyday life and potentially escaping its grasp. Mande people do not expect their technologies to neatly and fully match themselves. They always handle technology with care, as it comes from an alien world, never being able to have the guarantee that it has been fully socialized for good. What escapes human’s grasp permeates technology because, for Mande people, culture and chaos are not two impermeable worlds; they are rather interconnected by a fluid and porous boundary. Mande blacksmiths, accordingly, are always aware of their liminal nature and the opportunities but also responsibilities attached to their role (McNaughton, 1993). On the contrary, in the global North, technology is perceived as what has emancipated human beings from the laces that would make them pray wild and invisible forces, being these spirits or God. Even if debates about technology being either a blessing or a curse are a constant through history, with Enlightenment people perceived that the light of reason arrived to illuminate and get rid of the shadows inhabiting Middle Age darkness. Nowadays, we rely on technology for an increasing number of activities and processes of the daily routine. The goal of designing technologies that match quite fully their users by thinking, behaving, and even feeling as humans is not just a technological utopia but a present reality. In last years, the wondrous advances made by the technological infrastructure, which is able to make sense of big data, have increased both hopes and fears of technology being able to redesign a better future. As a consequence, technology-related professions are gaining both increasing recognition and scrutiny.
5. Beyond common concerns: letting data be otherwise

5.1 Critical big data/algorithm studies
A transdisciplinary debate, called ‘critical algorithm studies’ or ‘critical big data studies’\(^1\), is pursuing the aim to analyse the merits and the faults around the epistemology and related politics of these technologies of prediction and construction of tastes, attitudes, opinions, ideas, ideologies and behaviours. To summarize this debate, Neff and colleagues (2017) have identified the main critiques mobilized against data scientists, which are 1) to consider data as objective rather than the product of interpretative practices, 2) to abstract data from their context rather than to recognize their embeddedness in the context, 3) to reify data without considering the socio-technical apparatus that produces them, 4) to not acknowledge the fact that data are a means to negotiate, produce and reproduce social and cultural values.

The tone employed in advancing these critiques creates an “algorithmic drama” in which “algorithms are figured as powerful, inhuman, and obscure, leaving critics and their readers to fight on behalf of humans (Seaver, 2018, p. 377). More often than not, these critiques proceed from an ideological position, ignoring how things really work in data science and at the expenses of the possibility to create genuine and productive interdisciplinary collaboration. The second Author has instead embarked on a long-term ethnography of data scientists in the field of computational biology (Raffaetà, 2020) and this experience made her understand that data scientists are usually well aware of the considerations listed above (at least the first three). She could observe how data scientists are not data fundamentalists but critical thinkers, who care for the context, its interpretation, and for data infrastructure. This has also been illustrated by others studying diverse communities of data scientists (Leonelli, 2016; Lowrie, 2017, 2018; Seaver, 2015).

Yet, what all these studies agree on is that the way in which data scientists make sense of ‘context’, ‘values’ or ‘culture’ is highly formatted by their epistemic practices. In the case analysed by the second Author, for example, the context considered by data scientists rarely exceeds the walls of the molecule and the most rewarded value is parsimony (in informatic terms) and efficiency. This is very different from making sense of data as part of a context that always, already and necessarily exceeds human’s grasp and understanding, as Mand do in constantly reminding of the inescapable connection between spirits and technology.

5.2 Ethical concerns
These epistemological concerns are linked to the main debate that revolves around data-driven technology and society, which is ethics. This centres on users’ privacy, new forms of mass surveillance and the exacerbation of inequalities. For example, the concept of “surveillance capitalism” underlines the peculiarities of present-day information capitalism

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\(^1\) For a list of readings and other resources, see [https://socialmediacollective.org/reading-lists/critical-algorithm-studies/?blogsub=confirming#blog_subscription-2](https://socialmediacollective.org/reading-lists/critical-algorithm-studies/?blogsub=confirming#blog_subscription-2)
driven by data (Zuboff, 2019). Similarly, the notion of “sensor society” (Mark Andrejevic & Mark Burdon, 2015) contributes to shed light on the “dark side” of the algorithmic prediction of behaviours. Nowadays, the collection of information is less and less purposeful and active, and increasingly pervasive and automatized, the users generating data inadvertently, while they go on with their everyday lives. This is the case, for example, of mobile phone users who generate data on where people make calls, what websites they visit and for how long, etc. This amount of data eclipses the data they actively communicate in the form of text messages, emails, and phone-calls, as the device is doubled as a sensor. As a result, data miners’ practices are opaque, aiming at correlating rather than interpreting bits of information, and the users have little chance to become aware of their data extraction, feeling rather powerless and intimidated by the complexity of the automated intelligence (Mark Andrejevic & Mark Burdon, 2015; Zuboff, 2019). This brings to the forefront the emergence of new inequalities and discriminations, that draw a line between those who mine and those who are mined (O’Neil, 2017).

5.3 The socio-cultural risk
But beyond these well-debated epistemic and ethical concerns, with this paper we want to bring attention to the socio-cultural risks advanced by designing data without letting space for data to be otherwise. What do we lose by living in a technological world which assumes that we can grasp everything and that aims to fully match our wishes, ideas and behaviours? Will the sense of familiarity and safety we could gain in such a world be able to reward us for the losses?
To live in a technological world which is designed to match as much as possible users affects the viability of “escape routes” (Favole, 2018). According to Favole, “escape routes” are critical moments, during which the normal flow of events is suspended and unexpected occurrences may happen. These moments of “crisis” foster people to think out of the box and to rely upon improvisation and creativity. Following this perspective, when objects run wild, not performing as we might expect, spaces of possibility open up, where to think and act differently (Jackson, 2014). These are “leaks” in the status quo that should not be “plugged” but let them flow as they carry with them cultural dynamism. They come together with feelings of estrangement and unsettlement, which force people to change their perspective and experiment with diversity.

6. Conclusion
In this paper we have drawn a comparison between data scientists/designers and Mande blacksmiths to draw attention on the emerging feature of aliveness of technology and the scientific and socio-cultural consequences that come with it. Both Mande technology masters and global North data analysts are seen by ordinary people as liminal figures, who straddle culture and nature, society and the wild realm, bearing secret knowledge to tame the untamed (being this knowledge either ritual formulas or secret algorithms). Their special skills consist in the ability to articulate and connect different realms, assembling together
Designing unpredictable futures

raw materials and culture. In doing so, they concentrate in their hand exceptional power, which is regarded as both dangerous and salvific by the rest of the population, who is somehow aware of the fact that they forge technology and society at the same time. While Mande blacksmiths and data designers have many things in common, one aspect distinguishes them dramatically. This is the attitude put into being in translating a wild and chaotic world (of spirits or data) into a cultural one, adapted to human needs and wishes. Usually, epistemic and ethical concerns are those mostly at the forefront, but the “longest way round” offered by Mande blacksmiths sheds light on the socio-cultural risks of designing data without letting space for data to be otherwise. A world with no “escape routes” is not just an intellectual problem: it has concrete consequences on how we live because ‘culture’ it is not made of abstract ideas but it materializes in how our lives are shaped by objects, infrastructures, norms, relations, etc.

To ask designers to let “escape routes” to data - and to us - it is not being naive or against technology. We acknowledge the great benefits technology has brought to humanity and its power as an inescapable and creative force in tracing humans’ path in this world. That’s why we care for technology and how it is made. Clearly, we are not advocating for a technology we cannot rely on or that fails. What we aim to address to designers with this paper is to reflect on which solutions and routes they can devise to continue to make our lives better while keeping open routes for wonder, surprise, regeneration and change.

By promising intimacy and perfect mutual understanding, smart objects and environments risk impoverishing culture of its escape routes towards the untamed. This is, indeed, a source of regenerating chaos, from which to learn to tackle and to come to terms with the unknown. Is the selfie the best metaphor of this dynamic, where people mirror themselves as they look at the world, the technology and the surroundings becoming a projection of the self, without any chance to grasp anything else?

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Digital Creativity Tools Framework

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Abstract | The objective of this study is to define a framework for clustering and analysing digital tools that facilitate the Design Thinking process. The framework, based on an extensive literature review, is developed as part of a more articulated and complex ongoing research aiming at identifying the most crucial factors that influence creativity in the digital era. The purpose of our model is to map and classify digital tools in order to support designers to face the digital transition. This study outlines the way in which we produce new ideas and different forms of knowledge through a creative design process by adopting digital technologies.

KEYWORDS | DIGITAL TOOLS, DIGITAL CREATIVITY, DESIGN THINKING, CREATIVE PROCESS
1. Introduction and aims

In the last years, the integration of new digital technologies has been used not only to innovate products and services, but also to support and foster the creative design process.

Increasingly, the digital era and its technologies are having a profound influence on the digitally enhanced generation (Prensky, 2009) who need to develop new competencies and skills among which human creativity is the most important one. It is, therefore, becoming essential for the design research to understand how digital technologies are influencing the creative process and creativity abilities to develop appropriate tools and models for the next digital generation of designers representing the actors of a near future. Indeed, designers are facing a digital revolution which required them to be prepared to work in an interactive digital world in which everybody does design (Manzini, 2015) in order to address new technological challenges achieving large-scale innovation.

The digital transition is also affecting the tools that designers adopt to follow the different steps of the design process such as gathering and sorting different information or generating project opportunities and identifying new directions. There is some confusion as to which tools and techniques to use, when, and for what purpose. Therefore, we are proposing a framework to help organize the proliferation of tools, techniques and methods in hopes that the design community will benefit by discussing relevant applications and identifying potential areas for further exploration. The framework that deconstructs the design process into phases and tasks and defines the taxonomy criteria for clustering the tools that could potentially play a role in all stages of the design process.

Starting from our expertise and knowledge about the Design Thinking approach (Meinel & Leifer, 2015, Canina et al., 2020) we analysed for each phase of the design process which digital tools could be applied to facilitate design activities. All the tools identified during the research could enhance designer and non-designer’s creativity in different terms, some of them are more design phase-specific and others are more collaborative or linked with the entire design process.

To identify the methodology with which to structure the framework it is essential to consider the several forms of support that facilitate or improve designers’ activities:

- design methods to facilitate the process of product development (Araujo, 1996; Schneider & Lindemann, 2005) or to help designers better understand users’ expectations and needs (Wharton et al., 1994);
- ergonomic principles or recommendations (e.g., Norman, 1993) and ergonomic criteria (Scapin & Bastien, 1997) to help designers create products or objects that are more adapted to users;
- computational systems that aim at supporting designers at several stages of their activities (Fischer et al., 2005; Maher, Kim & Bonnardel, 2010).
The framework will deliver a repository of digital tools, as computational systems, based on the steps of the design thinking process could support designers during the stages of their activities, empowering creativity in different contexts, improving products and services on a holistic level.

2. Digital Creativity

Creativity has a fundamental role in the design process, is not the domain of a few called “creatives”. Every creator throughout the design process should be guided by creativity in order to enrich his project with new insights and innovation opportunities.

By the coming of digital technologies, designers started to adopt the new potentialities offered by the latter. They recognise certain possibilities allowed by the digital, but also emphasise that there may be certain kinds of limits that get left out when engaging with digital technologies.

This belief was born when platform and digital tools began to appear, which is the same moment the definition of Digital Creativity was coined. Lee and Chen, (2015) describe it as: “All forms of creativity driven by digital technologies. In other words, digital creativity occurs when digital devices are used for various creative activities”.

Digital Creativity is the result of a creative process implemented by a computer aided technology. Every time we employ tools or platform for supporting our creative thinking, the digital technology dynamics and mechanics influence creativity principles, that are motivational, cognitive, and attitudinal constituents of the design process. (Corazza & Agnoli, 2015).

Digitally supported creativity encompasses the study of how creativity can be supported and enhanced by digital technologies. Digital creativity technologies support many different kinds of artwork in digital representation (text, layout, image, sound, 3D object, moving image, etc.) as well as new form of art such as the generative art. The technologies also enable us to capture, store, manipulate and output these representations to produce media forms we can experience.

Within the computer science field and the HCI domain digital creativity is studied from a technological perspective testing and studying the application and potentialities of specific digital technologies for creative achievement. By approaching the HCI field, emerged that one of the main recognized research works has been done by Ben Shneiderman (2000, 2002, 2007) that has always undertaken study on “Creativity Support Tools” (CST) intended as user interfaces or software supporting creativity across domain, empowering users to be more productive, and more innovative. As he states (2000)
“the goal of designing creativity support tools is to make more people more creative more often, enabling them to successfully cope with a wider variety of challenges and even straddle domains”.

In 2005 he organized the workshop, “Creativity Support Tools” sponsored by the National Science Foundation, with the main aim of accelerating research on this topic and defining guidelines for the design and development of these tools. According with the result obtained (Shneiderman et al. 2005), a CST should enable more effective searching of intellectual resources, improve team collaboration and speed up the discovery processes. They should also provide support in hypothesis formation, speedier evaluation of alternatives, improved understanding through visualization, and better dissemination of results. HCI apply digital technology to develop tools that could enhance and support some aspect of the creative process that allow individual or a team of individual working together in reaching high performance. From the workshop are emerged several concepts, types of practices, and aspects of human cognition as important ingredients for research on tools for supporting creativity. For our research is useful to acquire the outlined roles of tools for supporting creativity, positioned in terms of three dimensions (Nakakoji, 2005) in order to analyse in deep the hypothesised taxonomy for the framework.

The first dimension includes tools to train people to develop creativity, or skills of creative thinking. Such tools aim at helping people to develop skills to engage in creative ways of looking at problems and framing solutions by using these tools.

The second dimension includes tools to support people's creative process while engaging in a creation task.

The third dimension includes tools to enable people to have new kinds of experiences that they would not be able to have without using these tools allow people to engage in completely new experiences of producing expressions.

These three dimensions, in particular the first and the second one, are the lenses adopted to scout the digital tools to be included in the framework since they are well connected with the design process structures behind the framework.

2. Methodology

The construction of the framework followed three main steps:

- The definition of the design process structure that was mainly based on one side on the authors expertise and knowledge.
- A literature investigation to identify and select the criteria on which based the framework and the scouting of design tools.
- A scouting of web-based design tools and their positioning within the framework.
An extensive body of literature have examined and discussed - within the digital creativity domain - the characteristic and design principles to guide designers in building efficient digital design tools.

Within the review we decided to focus on three main contribution provided by Shneiderman (2002, 2007) (Shneiderman et al., 2005) that clearly highlight design principles for building creativity support tools. Modern creativity support tools enable new forms of expression for individuals, and they are especially potent in supporting group collaboration and social creativity.

“Creativity support tools extend users’ capability to make discoveries or inventions from early stages of gathering information, hypothesis generation, and initial production, through the later stages of refinement, validation, and dissemination.” (Schneiderman, 2007, p. 22)

The guidelines for designing these tools address the design process and the creative principles within the design process.

From the analysis of this contribution 12 design principles that highlight the relation between digital tools and the creative design process have been extrapolated (Figure 1).

The identified principles have been analysed, elaborated and clustered in order to support the construction of the framework. The 12 principles have been indeed transformed into three main elements:

- **Design process activities:** this represent the most relevant activities that can be supported by a digital design tool. The activities have been defined within each process phase and are relevant for building the framework structure.
- **Tool’s selection criteria**: these criteria are relevant for determine which tool can be selected and included in the framework
- **Tool’s cross characteristics**: these criteria are fundamental to analyse and identify the different traits of the design tool collected. Digital design tools that are classified within the same design phase and that support the same design activity, can have different cross characteristic.

These three elements contribute to define the framework and the taxonomy with which select, analyse and classify the digital design tools.

### 3. The framework

The evolution of Design Thinking has been continuous, and the original paradigm has changed frequently and has acquired new names and facets.

In line with the evolution of the paradigm also the processes of Design Thinking changed, despite this in the last decade, four are the ones most used by the organizations. All these methodologies divided the Design Thinking process into many different phases, someone prefers to use a more linear path others adopt an iterative loop process. The names of the steps are different by the approach and the criteria behind these processes are the same (Figure 2)
The design process model adopted for building the framework, comes from the experience and background of the authors on the topic. Indeed, we adopted the IDEActivity process as the specific Design Thinking approach (Canina et al., 2020).

Using the study of various most significant existing models as a springboard - the 3I model (Brown and Wyatt, 2010), the Double diamond model by the British Design Council, the Service Design Thinking proposed by Stickdorn and Schneider (2010) and a key reading in Human Centred Design (HCD, IDEO 2011) - the IDEActivity process model was developed and the user is recognised as having significant creative potential. IDEActivity process model adopt a stage configuration based on the two main moment of the design process called Explore and Generate. For the two main stage of exploration and generation, it includes
different steps, from Clarify Goal and Define Opportunities in Explore, to Ideate and Prototype in Generate (IDEActivity Toolkit, 2017). Each stage is always constituted by a first phase of divergence, which is followed by a classification, and finally convergence to arrive at the definition of the problem or a solution. The Creative Diamond (Tassoul and Buijs, 2007) is characterised by a diamond shape and its phases have specific rules.

In order to build the basic structure of the framework, have been extrapolated from this model the 2 main stages, and the steps to be carried out during the process that represented the four cluster within which we placed all the digital tools.

3.1 Design process structure and activities

The Digital Creativity Tools Framework is based on a simplified yet exhaustive version of the human-centred creative design process that, using the potential of creativity and the approach of design thinking, support individuals from different backgrounds to actively experience the development of ideas or strategies.

The process focuses on two main consequent stages, Explore and Generate, and a total of four explicit process steps, each one with specific objectives, and each one characterized by specific activities. The activities have been determined and integrated thanks to the literature investigation of design principles for creativity support tools.

The first stage, Explore, allows the creation of a basis from which a significant and potentially viable goal can be defined its possible development in relation to a given context. Within this stage an understanding of needs, hopes, and aspirations is crucial, and an analytical process of information interpretation is fundamental to identify opportunities.

Explore is divided in two main steps: Clarify goal whose aim is to bring the goal clearly into focus and Define Opportunities whose is to transform the information collected in design opportunities.

The activities emerged from the literature analysis and integrated within these two steps are: Searching, Empathising, Clustering/Visualizing, Open possibilities, Prospecting

The second stage, Generate, aims at the generation of suitable concepts in line with the given context and the prototyping of innovative ideas.

Generate is divided in two main steps: Ideate whose aim is to generate one or more novel ideas which is meaningful for the design challenge framed, and Prototype whose aim is to enrich and refine the idea, through the development of tangible artefacts

The activities integrated within these two steps are: Inspiring, Conceiving, Selecting, Making, Reflecting (Figure 3).
**Fig. 3. Design process structure and activities.**

**Table 1. Summary of the design process structure and activities**

<table>
<thead>
<tr>
<th>PROCESS STEPS</th>
<th>ACTIVITIES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLARIFY GOAL</td>
<td>Searching</td>
<td>Accelerating the collections of information. A task which people undertake to find or retrieve specific data and resources.</td>
</tr>
<tr>
<td></td>
<td>Empathising</td>
<td>Analysing user behaviours and creating harmonious relationships with him, to collect information about actions, feeling and emotions of others.</td>
</tr>
<tr>
<td>CLARIFY GOAL / DEFINE OPPORTUNITIES</td>
<td>Clustering/Visualizing</td>
<td>Grouping the large amount of data gathered and having a better visualisation of them, helps designers to organize their knowledge, see relationships, and possibly spot what is missing.</td>
</tr>
<tr>
<td>DEFINE OPPORTUNITIES</td>
<td>Open possibilities</td>
<td>Tools that show you all the possible implications of decisions. Enhancing the conception of which possible scenario might be done or might happen.</td>
</tr>
</tbody>
</table>
### Prospecting

Converging all the possibilities in a specific scenario or future event

<table>
<thead>
<tr>
<th>IDEATE</th>
<th>Inspiring</th>
<th>Being mentally stimulated to do or feel something, especially fostering creativity. Collecting and combining immediately your ideas in order to get new inspirations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceiving</td>
<td></td>
<td>Inspirations bring you to a list of ideas that have to be simulated in all their possible implications of decisions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IDEATE/PROTOTYPE</th>
<th>Selecting</th>
<th>Making a decision on the strongest and most impacting ideas.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTOTYPE</td>
<td>Making</td>
<td>Building and composing artifacts, prototypes and performances. In order to test all the possible implications of the product/service.</td>
</tr>
<tr>
<td>Reflecting</td>
<td></td>
<td>Disseminating the final solution to all the stakeholders involved, in order to gather feedbacks to play with, to experiment with, to talk about.</td>
</tr>
</tbody>
</table>

### 3.2 Tools scouting and analysis

The inquiry that has been conducted, started with an analysis of the basic design tools for Design Thinking. Both for illustrating the state of art of analog tools and to give an exemplification of what kinds of techniques design currently offers. Secondly, we determined to go deeper in terms of specificity and to cluster a series of digital tools who could enhance the creative approach for each phases of the design process.

Two main general criteria have been identified for the selection of the digital tools:

- **META-DESIGN.** Creativity needs the “synergy of many” (Benkler, 2006) and this kind of synergy can be facilitated by meta-design. Meta-design is a socio-technical approach that characterizes objectives, techniques, and processes that allow users to act as designers and be creative in personally meaningful activities (Giaccardi & Fischer, 2008).
- **LOW THRESHOLDS / HIGH CEILING.** Tools should be easy for novices to begin using, they should not be intimidating, and should give users immediate confidence that they can succeed. At the same time, the interfaces should be
possible for experts to work on increasingly sophisticated projects (Shneiderman et al., 2005)

The two specific criteria used for selecting the tools are related to two dimensions mentioned earlier:

- Tools enabling creative thinking in the different step of the creative process.
- Tools supporting the steps and activities of the creative process.

Each collected tool has been analysed firstly to identify which step of the process and which activity can support. Secondly, it has been analysing according to 4 criteria that allow to specify some characteristic of the tool that are transversal to all the steps and phases of the process. These are:

- **COLLABORATION:** The tool enables a sharing system and a safe environment that allow team members to contribute and work on their own parts in parallel, supporting the integration and iteration, building trust.
- **RICH HISTORY KEEPING:** the tool allows to record the process history and which alternatives the users of the tool have tried. The tool allows them replaying session histories, comparing the many outcomes and going back to earlier ideas to make modifications.
- **CO-CREATION:** the tool allows an expert facilitator to plan, modify and adjust co-design activities in which different parties work together and jointly produce a mutually valued outcome.
- **RELATE AND INTERACT:** the tool utilizes any form of communication for consulting with peers, experts and mentors for clarify requests and intellectual and emotional support.

From the collection emerged that some of the tools are mainly used by a design facilitator for training and co-design sessions with a larger audience (i.e Stormz) and others can enhance real-world interaction, discovery, exploration, and imagination through Augmented or Virtual Reality (Zünd et al, 2015).

Some of them are phase-specific digital design tools that are online platforms or tools repository with a high level of specificity, which support one specific phase of the process. Here we can find for example tools characterised by computer-mediated brainstorming, tools that allows to capture plans and ideas in a web-based virtual whiteboard (i.e. Miro), or others only for testing and evaluating already existing prototypes (i.e. Proto.io).

Others are considered as multi-phase design tools that are all those platforms that could keep track of the entire process. They are totally cloud tools that allow the collaboration between team members to develop new projects, from ideation and envisioning to gathering feedback directly from users. (e.g. Shape by IDEO)
3.2 Digital design tool positioning: Shape

For each tool analysed a card has been designed, indicating the Name of the tool, the Cross characteristics it answers, a description of how it supports the activity/activities of the process, and a link (Figure 4). Each card is then visually located in correspondence with the process activities he supports or empower. In this paragraph an example is described.

Shape (IDEO) is a visual and collaborative environment for building, testing, and refining ideas. With respect to the design process, the web-based tool allows to engage and guide a team of people through all the steps of the design process also providing template to let people get quick access to convert the ideas. It allows to gather inspiration and ideas creating visual spaces to brainstorm a new idea or share design inspiration across a team.

Among the cross characteristics is possible to identify that Shape it is a platform designed to guide and support collaboration at multiple scales, from small teams to large organizations and global communities. Shape allows to guide, document and manage the creative process of a team of people who is solving a challenge, in a transparent way. It has been designed for simplify communication between the designer and its customer, allowing the latter to enter in the process, understand the main steps and contribute, and to easily relate and interact for request feedback directly within the platform. The visual support facilitates evidence-based decisions and allow to keep track of the best practice analysed, the idea shared allowing people in going back and iterate on the process done.

![Shape tool analysis card](image)

**Fig. 4. Shape tool analysis card.**

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1 [www.shape.space](http://www.shape.space)
4. Conclusion

The research and the development of the taxonomy and the framework wished to identify some of the characteristics of the digital tools that nowadays designers can use in order to expand their minds and visions. As Literat and Glaveanu (2018) affirm, this new typology of tools emphasises individuals and individual minds. In fact, it is exactly the emergence and growth of digital technologies that contributed to new, systemic ways of thinking and talking about creativity.

The developed taxonomy highlights tools intended for a wide variety of uses and varying in complexity, from a simple tool with one specific function to multiple function tools or an entire suite of tools. The framework allowed us to characterise every tool with its own phase of intervention in the design process, and to identify areas in which nowadays there is an absence of supporting tools. We can, therefore, assume that the generated framework will benefit several contexts and open opportunities for other future researches. For example, it could support companies aiming to adopt digital creativity tools for exploring and anticipate design opportunities and needs. In the design field, it could shape new digital creativity tools to support designers at all stages of the design process and to diverge their thinking and get carried by lateral thinking.

This research is at an early stage and does not have the ambition to map all the existing digital tools that can support the creative design process. Only web-based digital design tools have been considered in this first scouting of tools.

The speeds with which these tools and digital technologies are emerging and developing would make the research never complete. The main aim is to identify in the different steps of the process the relation between the tools, the activities and the creative factors of the step itself, to facilitate the achievement of a more novel and useful result. Future directions aim at testing some of those tools in a real design setting, in combination or in comparison with other analog tools, to verify and understand what features can better meet the designers of the digital era works.

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Digital tools that support students to reflect on their design competency growth paths.

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Abstract | This paper reports on the design and testing of two digital learning systems. The first, STUDIO, supports individual and collective reflection on the design process. It allows design students who are undertaking a work placement in industry, to capture professional attributes they are acquiring and to share progress with their peers. The tool is intended to be used post facto, that is in supporting students’ self-reflection, to aid development and inform future work in the field of design. The second system, Trajectories, supports student journeys through a course of study. It is intended to be used live. As students proceed through their studies, acquire new skills, and deepen their existing knowledge they assess their own level of mastery of a specific competency on a continuous basis by connecting it to specific design outcomes.

KEYWORDS | DESIGN COMPETENCY, SELF REFLECTION, DIGITAL LEARNING SYSTEM
1. Introduction

We deploy the notion of design competencies to enlarge our inquiry beyond any one specific course of study. We understand competencies to be more than technical ability or mastery of domain knowledge and to include personal characteristics. These characteristics may include cognitive, social and emotional attributes (Dubois, 1993; Lucia and Lepsinger, 1999) deployed by designers in the production of their work. The idea of competencies thus emphasizes abilities beyond traditional studio design skills. Some theorists (Boyatzis, 1982) go further to include the environments and relationships featured in a particular context and the motivations and perceptions an individual may have of themselves and their abilities.

We contrast the respective educational and learning cultures of two design schools in London, UK and Toronto, Canada. In Toronto the system is used by undergraduate industrial design students doing a semester long work placement during the third year of their (four year) Bachelor studies. The professional nature of their work placement range widely, students may be placed at a product design agency but increasingly are placed in UX/UI firms, or service /experience design consultancies.

In London the system is used by an international postgraduate student cohort studying user experience design at master’s level. The London course is 35 week-long and ends with a final major project. The curriculum follows a cohort model with students working collaboratively in small groups on a range of projects throughout the course. As user experience design is a convergent discipline, students are drawn from many different disciplinary backgrounds including graphic design, media arts, art history and philosophy. Students may also wish to end up in a wide variety of design-oriented careers including user research, interface design, information architecture, or experience design. We have found that a competency-based approach works well to scaffold the many different pathways available to students.

We assume a set of positions regarding culture in this context and are in sympathy with Hall’s (2016) definition of culture as ‘experience lived, experience interpreted, experience defined’. Design students address this by reflecting on their own experiences, and reaching out to inquire about the experiences of others. Designers use a wide range of tools to explore, interpret experience from interviewing, observing, journey mapping, to drawing, story boarding, diagrams to coding, and impose constraints to define the experiences they are designing for. Hall also defined culture as a space of negotiation, open to diverse voices and responsive to people, places and languages. We take the view that culture can be thought of as national, institutional, pedagogical, social and individual. From this it follows that the learning process of a design student is situated within a constellation of these cultural dimensions.

Appreciating these complex and ever-changing cultural dimensions there is a necessity for students to be able to navigate and chart their unfolding learning pathways within and across these constellations. Findings suggest there is common ground in how both digital learning systems enable students to describe and tag their experiences with competency.
Digital tools that support students to reflect on their design competency growth paths

definitions to help them identify their current learnings, assess individual competency strengths and weaknesses and to inform future learning needs and required project work. Both digital, competency-based learning systems also show differences, most pronounced in how the systems are structured temporally and how they contribute to different aspects of a design student’s personal profile. The conclusions we draw from this comparison include the centrality of local pedagogical cultures, and the need for a multi-faceted and integrated curriculum that can stimulate self-knowledge.

2. Background

Development of digital learning systems covers a wide range of topics across the last two decades. Research into online classroom delivery in the early days of the web (Siegel and Kirkley, 1997) emphasizes the linked and dynamic nature of web-based information access, the threat to validity and integrity of material published outside established practices of editorial reliability, and the screen-based experiences of learning online. This work is followed a decade later by more systemic and applied approaches to digital learning systems that examine the challenges for learners of a digitized information landscape and look across at adjacent domains of knowledge and practice for methods that might be useful.

Peters (2000) uses the phrase ‘digital learning environment’ to describe how learning using digital technologies is a fragmented experience using multiple devices, operating systems and software applications. Prensky, (2003) identifies game-based learning as fruitful for engaging young learners, Clyde (2004) focuses on what she calls ‘digital learning objects’ meaning content items, communication tools, assessment items or learning management tools. The two projects we discuss in this paper could certainly be described as knowledge management tools but with the particular emphasis on the practice based creative learning activities that design education involves.

The introduction of the first iPhone in 2007 meant a turn in digital learning research towards mobile learning with the implication that digital learning systems imposed on students by University IT departments such as Moodle, or Blackboard would be rendered out of date. Jarvis (2010) points out the possibilities for ‘experiential field-based learning’ whilst also identifying that learners may end up feeling exposed and frustrated if the systems they use are unfamiliar. The transformation of the delivery of education and training by mobile learning is evident in examples from nursing, museums, and distance learning (Ally, 2009). In art and design education specifically, Heaton (2019) opens up a space for ‘collaboration, moral consciousness, and social responsibility’ in digital provision, suggesting a sensitization an alignment of art and digital practice, what she calls ‘curated cognition’.

We can thus see a transition from researchers interested in digital pedagogies from viewing them as a threat to established knowledge practices, to offering opportunity to learn from adjacent domains, to a systemic analysis of a fractured technological landscape. There can now be very few design education curricula with no element of digital provision. This might
include students using creative software, online materials such as theoretical readings, online marking and assessment, digital submissions in the form of blog posts and PDF files, or digitally enhanced outputs such as spaces and products.

The projects we describe in this paper are knowledge management tools for design students and are more accurately described as tools for creative reflection. Valkenburg and Dorst (1998) describe some cognitive tools for creative reflection used by design teams. These draw on Schön’s theory of reflective practice by attempting to specify how designers frame a problem, what actions ensue and how they are named by designers. Actions are captured in the concept of moving, meaning making choices and generating ideas. Mewburn (2012) positions actor network theory as a way to both challenge and enrich Schön’s notion that the design teacher is the source of knowledge for design students through demonstration of their own ‘artistry’. Instead, she suggests the design studio contains non-human technologies (actors) arranged in a specific relation to each other (a network) such as photocopiers, projectors, computers, desks, cellphones that all contribute to the pedagogical situation. We thus position that our own work on digital systems supporting creative reflection, as acting in a way that similarly constitutes a movable, individualized but peer sustained learning digital environment.

Tools for reflection are commonly taken to be abstract. Gray (2007) epitomizes this approach in a study of tools for reflection in management learning. He mentions storytelling, conversation, dialogue, metaphor and analysis as tools for reflection in the learning process for a student of business management. Where technologies are used to support reflection in education they tend towards presenting portfolios of completed tasks for students to reflect upon (Oner & Adadan, 2011; Oakley et al., 2014). Both Studio and Trajectories feature aspects of this function but are more oriented towards collaborative, generative and the kind of abductive reasoning common in design (Kolko, 2010). The projects discussed in this paper express the generative nature of design work and the ways in which learning design involves students making things that have not existed before. So, while our tools may encourage abstract qualities in the process of reflection such as conversation, storytelling and metaphor, these are understood to be fundamental to design learning and thus arise in the doing of design work.

Resnick et al.’s (2005) set of principles for tools that support creative thinking epitomize another strand of research in the field of digital tools for creative work in design. We are in broad sympathy with these principles which include ‘support exploration’, ‘support collaboration’, ‘design for designers’ among others. We note however that they are oriented towards software that designers can use to create their designs such as image manipulation tools, or 3D modelling applications. Instead our focus is on facilitating reflective evaluation of the process while creating design work, and reflection and evaluation of the work once it is completed.
3. STUDIO

The Toronto University has a department to support emerging artists and designers. This department has identified ‘self-learning’ and ‘self-reflection’ as critical capabilities for students doing internships. To help foster these capabilities in students, they have explored the use of on-line tools and mobile apps that can support student in their self-reflection processes.

STUDIO is a smartphone app that responds to this need. The application features four main functions. Firstly, students can use STUDIO to write down and document their everyday reflections on what they do and learn during their work placement. Secondly, the app provides a series of probing questions to stimulate thinking about the learning in their everyday interactions. Thirdly, STUDIO allows students to add photos and text annotations to their entries. Fourthly, STUDIO has sixteen predefined tags, each representing one of the professional practice competencies that are associated with experiential learning. These professional practice competencies have been defined and curated in collaboration and consultation with teaching staff in faculties of Art and Design and with experiential learning specialists.

By tagging each diary entry with up to three competencies students build a visual representation of the competencies they are growing in, those that they face difficulties with, or those that are lacking. This provides opportunities for identifying gaps in learning and validating individual strengths. Students can choose to share their learnings with their peers or not. If an entry is sharable, the student can open their entries for feedback. In this way STUDIO works as a social network of students who are engaged in a workplace learning experience.

Figure 1) features a Material Art & Design student STUDIO entry on a field trip to an artist residency, remarking on the relation of the environment and the students’ creative process. Figure 2) features an Industrial Design student STUDIO entry on an exercise in which students disassemble a mechanical object, and probing the relationship between mechanical artifacts and the materiality of its components. Figure 3) features a Material Art & Design student STUDIO entry on an exercise in which the student was organizing existing fabric pieces along their color, remarking both on the creative process and the role of hands on, tangible learning.
STUDIO has been tested by two groups of five students each. Group 1 used STUDIO in a structured context as part of a Design Internship Placement Course, and Group 2 used STUDIO in a more unstructured situation by students that were enrolled in an independent Field Studies. For Group 1, STUDIO was integrated into the placement experience. Key features of this group included requiring students to submit one post, one comment, and one response every week during the semester. Discussions related to posts and comments occurred during every in-class meeting and was integrated into final presentations. During the first week of introductions, students were introduced to the Benchmark Activity, which features a printout of the sixteen competencies and asks students to identify the competencies they want to work on or improve. They were then asked to select 12 out of 16, then 6 out of 12, then 3 out of 6, and 1 out of 3. An in-class discussion around their final choices then took place. In the final session students were asked to complete the benchmark activity again. They were asked to identify the competencies that they worked on or improved throughout their placement. There was then follow-up discussion around the students’ personal experiences.

For Group 2, there was an unstructured integration of the app into the placement experience. While students were given a tutorial and encouraged to use the app, there was no established structure for how the student should use the app, nor minimum engagement requirements. Group 2 received no reminders apart from a mid-term and year-end check in.
Feedback from the testing process shows a number of findings. Students felt empowered by the immediacy and visibility of their entries, particularly that they were able to see entries of their own and their peers. The list of competencies was very useful in establishing terms and framing the internship learning outcomes - ‘a great way to make sense of the experience’. The terminology made it easy to associate moments in the workplace with what was covered in class. The brevity of the entries ‘took away some intimidation related to reflection’ allowing timely and relevant reflections related to the placement because each entry was expected to be so short. One student was excited about the potential to take notes about some of the things she was facing as they happened. She felt that ‘using a cellphone would be fast and easy compared to having to remember thing and write them down when I get home’. Negative feedback included difficulties creating an account and logging in, and accessibility problems with a screen reader unable to read all menu items. Navigation was an issue ‘the UX means it is not clear how to navigate the posts, I felt the process was complicated and not totally intuitive’, ‘I could use more guidance in the app on how to use it’. More detailed comments include ‘it would be good to be more open ended and have a framework for structuring thoughts’ and ‘the ability to export or share selected posts both private and public would allow this to become part of graded assignments’.

In summary, there is clearly more work to do to develop STUDIO, particularly around integration with course curricula and accessibility, but the ability to frame the informal learning that takes place during a workplace internship in terms of competencies that relate to specific activities helps students keep track of, and share, what they are doing and how it is valued at program level.

4. Trajectories

MA User Experience Design (UX) at the London based university is a 45-week Postgraduate degree. Students come from many different cultural backgrounds including from China, Italy, Brazil, USA, Ireland, Korea, and India. Students also have diverse educational backgrounds in graphic design, product design, philosophy, architecture, finance, computer science and marketing. UX is an integrative and convergent discipline and provides creative opportunity in fields such as design research, user interface design, interactive prototyping, creative coding, interaction design and increasingly, service design and experience design. There are thus many pathways or trajectories through the program that means students, even while collaborating on the same project briefs, may have different goals and end up with very different design abilities. Trajectories is a smartphone app that addresses these many possible routes through the program by using the competency model we have explored in previous work (Fass et al., 2017, 2018). Like STUDIO, students choose a maximum of four competencies from a grid of sixteen per project. The sixteen competencies are the result of two years research and consultation activity including workshops with staff and students. They are intended to provide a set of choices for students to decide what they consider to be their existing strengths and what they wish to be better at. The focus of Trajectories is on...
completed and ongoing design work. Competencies are thus connected to visible and shareable output. Projects are connected to assessed program units, and specific design briefs. On launching the app students must initially populate their profile with a project including title and image. Then four competencies are attached to that project and a level chosen for each one. Project work is described and made available to the whole cohort at various levels of visibility for peer and tutor feedback.

Trajectories is structured around three navigational principles. The first navigational mode ‘Timeline’ shows how an individual student is progressing through the program week by week. This gives an overview of competency levels per project as they develop over the weeks of the unit, and ultimately of the whole course. The second navigation mode: ‘Competencies’ shows the four specific competencies selected by the student that are associated with a particular project, with levels set in the most recent week. The third navigation mode: ‘Projects’, displays each project entered by a student. Projects have text descriptions (shown in Fig. 4) and are connected to units (shown in yellow boxes in Fig. 6).

Further detail about individual competencies is provided in order to describe what they mean, and how they are applied in UX. Most importantly, in Trajectories competencies are exemplified and explained through their application on projects that other students have completed or are currently working on. In this way we hope to emphasize through design example rather than theoretical description. Reflection is thus based on student output, allowing competencies a degree of latitude and flexibility in what they come to mean over time for individuals and groups. At the end of the program after 45 weeks students can
Digital tools that support students to reflect on their design competency growth paths

orient their graduating portfolios and career aspirations towards those competencies that they can provide evidence for in the work they have done.

Trajectories has been tested by 12 students by asking them to use the app in prototype form as they worked on a design project and provide spoken and written responses on their experience. Positive feedback includes comments about the depth of explanation ‘I like that there’s a definition for each competency since this is the first time I have encountered the idea’, and the learning style enabled by a competency framework ‘Tracking the competencies allows for a much more relaxed learning experience instead of a strict marking scheme.’ Using competencies to frame the learning journey allowed students to reflect on their current learning position - a snapshot of how they are doing on the course and why, ‘By breaking down what there is to be learned in this way it helps me to what I’m finding most interesting and why I want to develop those skills further.’ The system helps students to think about their future development. The navigation mode ‘Competencies allow me to break down the skills I believe are important to have, the skills I have already started to develop and what other skills I can develop’ and position themselves in the broad field on UX design.

The emphasis on projects as a way of demonstrating competencies through completed design work, rather than written reflection alone was seen as valuable because it recognizes the practice-based nature of the course and ‘lets us showcase exactly what skills we are using and how those skills develop through different kinds of designed outcomes and topics this in turn allows us to see where our strengths lie by adapting to these different topics of research and design.’ Having a personal portfolio of projects helped students understand and identify their strengths, how those strengths have been expanded and how they might be reflected in career opportunities ‘It (projects) helps in understanding which skills I value most, use most often and have improved the most in over time through the course of individual projects and the entire course. The competencies themselves help me to see exact names of skills that could be found in job roles.’

Elements of the system to improve include a peer review function. ‘I feel some of the things missing are anonymized peer reviews allowing people to give one another advice on how to improve their competencies and help to keep evaluations of competencies honest’. A connection to careers in the field was also seen as useful ‘having a job roles page so that you can better match the competencies you are happiest improving with against what careers those combined competencies are best suited to.’

We can see from these reactions that the value is the system is in how it helps reflection on student development over time and hands control of the learning journey to students in a more granular way than summative assessments can provide. In addition, it can be difficult to stand back from everyday studio tasks and projects to gain an overview of how an individual might be progressing, Trajectories was seen to help this process. Finally, the connection with post-university career opportunities was identified as a current weakness
that can be improved along with some difficulties in navigation and data entry tasks. These will be a focus for the next phase of development.

5. Discussion

While it is early days for both these systems, there is much to build on. The implications for digitally enhanced pedagogy are related to levels of autonomy for individuals and groups, and to the possibilities for peer learning and review. By enabling self-assessment, the power of experts in design teaching situations (suggested by Schön in the form of ‘teacher artistry’) that was questioned by Mewburn (2012) is mitigated. Students are empowered to assess their own levels of ability in a particular competency and to elicit feedback from their peers and tutors on a level playing field. The flattening effect of digital systems (Fass, 2018) is here an advantage since teaching staff do not have privileged access to an individual’s feedback section. This chimes with Kulkarni et al. (2013) who find in a study of large online class using peer and self-assessment that there was high correlation with staff-assigned grading. In terms of pedagogy in design education it is clear that most forms of design today now include aspects of digital creativity. Students arrive for study at design school equipped with a sophisticated understanding of digital ecosystems, although perhaps not the critical ability to use them productively. STUDIO and Trajectories both validate a specifically digital approach to reflection and review. Some of the negative feedback from students shows how far it is possible to go and how high expectations are for a student facing a digital learning tool.

The implications for personal development and the individual learning journey are shown in the ways both systems have the potential to transcend their immediate context. In the unstable and unpredictable economy inhabited by creative professionals, who are more likely than other workers to be self-employed freelancers (Pitts, 2018; Merkel, 2019), sustaining a creative career over a lifetime of work can be a major challenge. The ability to identify strengths, and provide evidence for those strengths enables designers to continue to build their abilities after graduation and adjust to the ever-changing priorities of the creative marketplace. Critical reflection on competencies and on design work shows the kind of advanced abilities valued across the design sector and shown by Giroux (2018) to be fundamental qualities for ‘socially responsible and civically engaged citizens’.

The implications for design education are clear. Without access to tools; whether cognitive, abstract, tangible or digital for critical reflection students are at the mercy of the ‘disimagination machine that remakes social identity by turning civic subjects into consuming and marketable subjects.’, (Giroux, 2018).

Finally, the implications for a competency-based view of design education are validated by both systems. By emphasizing competencies rather than skills, abilities, or expertise students are encouraged to see themselves as acquiring a mix of complementary capabilities that may fluctuate in level depending on what they are doing, and who they are working with. The
Digital tools that support students to reflect on their design competency growth paths

Competency framework allows for self-identification by students with a set of competencies that can gain resolution and detail through design work over the duration of a program or a workplace internship, and ultimately over a creative lifetime. A competency-based view of design education also admits new areas of design such as bio-design or robot behaviors. In this way design curricula can be constantly updated within specific programs and respond in an agile manner to the emergent challenges of the age. Our future work in this area involves a global reporting project in the context of a Cumulus Working Group. We have elicited participation from over 30 design education institutions and 100 individuals who have agreed to contribute to an ongoing project that gathers the design competencies of the future, and provides evidence for how they are addressed in curricula worldwide and in student design work.

References


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Domestic AI and Emotional Involvement. Design Perspectives

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Abstract | The contribution addresses the current phenomenon of AI spreading in domestic environments but making no meaningful contribution to people’s life. The main purpose is to stimulate a conversation about the topic in the design community, trying to trigger critical reflections through the envisioning of – more or less – near future scenarios. Regarding the emotional sphere as a possible asset for the solution of the problem, the investigation starts from the field of psychology, translating some of the basic theories about (positive) emotions into scenarios where AI systems enhance houses, embodying these principles in an intentionally overstressed manner. Science Fiction Prototypes have been applied as research tools to build the scenarios and to infer critical points and interesting possibilities. The outcome of this work is a set of different envisioned futures that can be introduced in workshops and/or didactic activities to further advance the discussion.

KEYWORDS | ARTIFICIAL INTELLIGENCE, EMOTIONS, DOMESTIC ENVIRONMENTS, INTERACTION DESIGN, SCIENCE FICTION PROTOTYPES
1. Introduction

Referring to the topical issue of AI spreading in domestic environments, with no effective results, this argumentation aims at stimulating a conversation from a design perspective. Since we naturally invest objects and environments with emotional values (Branzi, 2013; Canter, 1972; Diani, 1988; Norman, 2004), as if they were a measure to assess experiences, we wondered if and how design and the latest technologies can improve our emotional well-being at home.

Starting from the analysis of psychological literature about emotions, to better understand the matter to design for, we explored 6 scenarios of a future life with non-human intelligence, each of them embodying a different theory about (positive) emotions. To guide the investigation, we employed Science Fiction Prototypes. This method allowed us to go further to almost dystopic scenarios, clearly stressing the main critical points and interesting possibilities they imply.

Finally, the outcomes of this experimentation are discussed and an integration of the scenarios in workshops and didactic activities is proposed to advance the debate.

2. Future AI-enhanced domestic life: a possibility for design

The transition towards a life of sharing our homes with non-human intelligences has already begun. The first wide-spread materialization of AI in the domestic environment is represented by smart speakers integrating virtual assistants: at the end of 2019 over 200 million installed units were expected, and the trend seems growing (Canalys, 2019).

Moreover, other AI-enhanced objects are emerging, namely lights, thermostats, doorbells, and even showers, while robots – varying from domestic assistants to pet substitutes – are multiplying (Hitti, 2020).

However, people’s relationship with this technology is controversial. Excluding the anxiety generated by filmic hyperboles depicting a world overwhelmed by robots, one of the most frequent sentiments characterizing the use of smart speakers is a disappointment, probably due to a lack of understanding, caused by the underlying invisible operations of these devices (Norman, 2004). Especially, when compared to the promises made by advertising campaigns, smart speakers fall below expectations, having issues in basic elements of interaction like discoverability and proper exploitation of functions (Kinsella, 2018; White, 2018).

Indeed, a positive impact of technology on people’s mood and life is key: Norman (2004) states that it should bring richness and enjoyment. Aware of that, brands delivering AI-enhanced products launch commercials leveraging emotional aspects. Accordingly, Amazon Echo is a tool to connect people or just the evolution of a human mate, while Google, emblematically states “You make a house a home. We make a home a nest”, overshadowing the product by highlighting people’s different emotional states at home.

The reality, though, tells us a very different story. Even if no deep investigations addressed the topic of smart speakers’ emotional impact, especially in the long run, we could intuitively
compare them with design theories related to (positive) emotions, to understand that they need further development. As anticipated, following Khaslavsky and Shedroff’s principles of the seductive power of design (1999), they excel in the enticement step with attractive promises, but miserably fail in maintaining them, and in making a memorable experience. Likely, whether they respond to an idea of novelty, favourably preserving the quite familiar aesthetic of a speaker, they do not always require the least effort to perform a task, contradicting the first and overarching beneficial feature Hekkert (2006) recognizes. As well, problems arise when it comes to the meaning of the experience, as it is difficult for them to respond to personal significance, virtuous (Desmet & Pohlmeyer, 2013), reflective (Norman, 2004), psychological, or ideological qualities (Jordan, 2000), even marking a rejection of sensuous curiosity and pleasure (Spallazzo et al., 2019).

These limitations, accentuated by the daily relevance they have in the domestic sphere, underline how AI represents a field full of possibilities for design, and the intervention – aiming at humanizing a technology which seems still too far from people – will need to take emotions in consideration because, as Minsky (2007) said: machines cannot be intelligent without any emotions.

3. Translating emotion theories in design scenarios

For a conceptual exploration, different theories about emotions have been adopted as literal guidelines to orientate the design process, in a sort of exercise in style. Sharing the spirit that drove Raymond Queneau (1947/2007) to experiment with literary variations of speech, our aim is to activate the creative engine towards unusual outcomes, and meanwhile, to collect different pictures that portray alternative futures and clearly embody the core principles of the currents of thought they stand for.

Future-focused thinking is one of the primary activities of design, especially when related to emerging technology research and the HCI field. For this purpose, the method of science fiction prototyping has been adopted. Considered an “embodiment of the third wave of design and HCI practices, [it has] the aim of capturing the essence of culture, emotion and experiences, and emphasizes the reflective role of the designer in HCI processes” (Kymäläinen, 2016). According to Dourish and Bell (2014), Science Fiction Prototypes (SFPs) as tools for design research could not only anticipate but actively shape the technological futures. In this context, SFPs are employed according to Keinonen’s model of design-oriented research (2006), as artefacts that may “open new spaces for design”, triggering critical thoughts and further speculations about the topic. In a reinterpretation of his model, here the phenomenon to be analysed (field of research) is AI in the domestic environment, while the framing for interpretation (in this case lying in the field of psychology and not of the art) are positive emotions, conveying focus and creativity to HCI. Design, instead, maintains its overlapping role to enable the communication between the other fields and brings, as an added value, its expertise to deal with the moment of drunkenness characterizing the introduction of new technology (Antonelli, 2018).
In the following examples, the authors created SFPs with the aim of envisioning domestic scenarios of a more or less near future, where AI exemplifies different psychological theories of emotions. In particular: 3.1, 3.2, and 3.3 address the issue in the most general sense and from a causal perspective; 3.5 and 3.6 express possible ways to pursue positive emotions; while 3.4 lies in-between. The outcomes are intentionally hyperbolic to stress their characteristics, and they show an individual-centred perspective, reflecting the ego-centric character of the psychological theories.

For the argumentation, Johnson’s steps to create an SFP (2011) have been followed. Here how they have been intended and indicated in the text:

(i) Technology enabling the scenario and set up of the world. (ii) Scientific inflection point – which dramatic change marks the transition to a new progressive scenario? (iii) Implications and ramification of the technology for the world. (iv) Human inflection point – how people’s life is modified? (v) Implications, solution or lessons learnt – judgments are intendedly avoided not to influence the reader.

All the scenarios portray future AI-enhanced houses, designed for people’s well-being according to the specific theoretical conception explained at the beginning of each SFP, and trying to highlight the key points of the technology: autonomy and adaptivity.

3.1 The physiological house

Literary reference. Emotions and the physiological responses manifested by human bodies are patently interrelated. In some of the earliest emotion theories of modern psychology, these physiological responses appear to be central in the definition of emotions themselves. In particular, there are visions sustaining that emotional behaviours are a direct consequence of the alterations revealed by the body, as the Peripheral Theory exemplify (James, 1884); while others just state that they occur simultaneously, it is the case of Cannon-Bard Theory (Lindzey et al., 1991). Anyway, modifications of skin conductivity, body temperature, heart rate, blood pressure and other possible reactions, if well balanced with contextual information, can make emotions measurable.

SFP. (i) Devices measuring and keeping track of our physiological parameters are already part of our reality, and they will be central in the physiological house. Smart bands and watches integrate sensors to monitor, among others, skin conductivity, heart rate and even heart rhythm for personal ECGs. Even Google’s installation A Space for Being at Fuorisalone 2019 used wristbands to assess whether people were at ease throughout three multi-sensorial domestic environments (Hitti, 2019a). (ii) To overcome the problem of environments subjectively affecting people’s parameters, AI systems, trained to evaluate contextual and personal data and to assess what the physiological responses stand for, are required. (iii) The physiological house will be characterized by a ubiquitous AI system that will have access to the physiological parameters of its inhabitants – wearing their opposite house bands – and will be in control of all the environmental facilities (lights, thermostat, music, etc.). Over time it will get to know how its users show their feelings and react to different situations. Then, as a caring mother, the house will interact with them by adapting the environment to people’s emotions for their well-being, or by sending messages on their
Domestic AI and Emotional Involvement. Design Perspectives.

(iv) Living in the physiological house will mean that, once at home, one has nothing to worry about: even before experiencing negative emotions, the house will have it all settled. Of course, at the beginning, there will be some misunderstandings, for instance, if one gets scared watching a horror movie, the house may turn on the lights and suggest him/her to call someone not to stay alone. (v) Inevitably, an ideal scenario takes time to settle because human emotions represent a very complex matter, and so many different data need to be triangulated for a complete overview. This would also implicate that a huge amount of power and digital/physical space will be necessary for the infrastructure of the AI system.

3.2 The neurological house

Literary reference. Emotional responses can also be attributed to the internal activity of the brain. Neurological theories suggest that emotions arise in the limbic system (Picard, 1997). Activating the amygdala, the anterior cingulate, or the prefrontal and somatosensory cortices (Damasio, 1994), emotions become an observable phenomenon: they leave a neural signature, identifiable through fMRI (Functional Magnetic Resonance Imaging) as a distributed pattern of activity (Kassam et al., 2013).

SFP. (i) Being able to access data from the brain and the nervous system is essential for the neurological house, and the premises to facilitate this task are emerging. In fact, Elon Musk’s start-up, Neuralink, is developing implants that can connect minuscule electrode threads to the brain, to record the detected electrical signals and transmit the information outside the body (Hitti, 2019b). (ii) Musk envisions the implant to create a symbiosis with AI, and this may represent the first sparkle for the neurological house. Everybody would have implants that AI systems integrated in the house will read, analyse and respond to, directly stimulating the appropriate part of the brain with electric impulses – similarly to the neurologist Duchenne de Boulogne eliciting emotion-related facial expressions by applying faradic shock on facial muscles (Duchenne, 1876). AI systems will be trained to recognize and reproduce emotional patterns in the brain, and their focus will be to understand its inhabitants’ preferred states and to satisfy their requests. (iii) Not much will be needed in the house to reach a balanced state of well-being, as positive emotions will be directly inferred through the brain implant. Furnishings and decorations will be superfluous, as only the survival-related equipment will be necessary. Secondary needs, like midnight snacks, will not be a problem as the right stimulus will quiet the hunger. (iv) Satisfying non-vital yet beneficial needs with no material aids will have several silver linings: it will increase people finances, as superficial goods or services will have no use, and it could even prevent health problems like obesity or drug addiction. (v) Nonetheless, the artificially induced constant positive state of mind will impede people to do anything non-related to subsistence.
3.3 The cognitive house

**Literary reference.** Cognitive theories of emotions indicate the element of reasoning as determinants for emotional behaviour. Two main currents are accredited. According to the Appraisal Theory (Lazarus, 1991), a personal automatic evaluation immediately follows an event, determining whether it is beneficial, non-relevant or harmful, then a suitable emotion is elicited. While, Schachter-Singer Theory (1962) hypothesizes that when we experience an event that causes physiological arousal, the resulting emotion depends on the motivation that our cognitive process recognizes. If no explanation can be found, we search the environment for clues as to how to label the physiological response, As emerged in an experiment (Schachter & Singer, 1962) people who could not understand that physiological responses of their bodies depended on epinephrine injections could be emotionally manipulated with induced cognition towards euphoria or anger.

**SFP.** (i) As cognition cannot be measured, a basic assessment of human-AI interaction has to come from external manifestations of emotions: body language, voice tone, etc. All functions currently under development. (ii) For the cognitive house, AI ubiquitous systems – in control of all the environmental facilities, including pervasive monitoring – have to be implemented with notions about what is beneficial for people’s well-being, and with their inhabitants’ preferences and goals. (iii) More or less subtly manipulating people’s internal appraisal of events, it will encourage well-being by changing the contextual conditions to trigger positive affects if it detects good behaviours or habits, or negative sensations if it spots bad ones. The house will act like a stubborn educator, ever conceiving new ways to get the better of them, and inhabitants will choose it precisely to achieve their goals. For instance, if one wants to get in shape, the house could low the temperature and make the lights colder to infer discomfort as (s)he eats sweets, or turn on energetic music to celebrate an exercise session. (iv) Either if the user perceives the intentions of the house (appraisal theory) or not (Schacter-Singer theory), (s)he will be encouraged to follow the right path. Though, the motivational process will not have immediate positive results, and people could quit early or endure and reach their goals. (v) In any case, AI finding a balance between physical (health) and psychological well-being (happiness) will be a challenge.

3.4 The activity house

**Literary reference.** In line with a phenomenological approach, Activity Theory, mainly explored by Leontiev, suggests that human perception of the world lies in the experience, and it is triggered by subject-object activities, intended as purposeful, transformative (Kaptelinin, 2014). Even though it does not directly address to the nature, function and underlying mechanisms of emotions (Kaptelinin & Nardi, 2009), it can be inferred that they may be a consequence of experience. In particular, Csikszentmihalyi (1990) identified the highest level of well-being in the condition of Flow. That means being immersed in an activity which lies in a balance between one’s skills and perceived challenge.

**SFP.** (i) The activity house, as the name implies, will pursue an active home life. For a dynamic interaction, AI should focus on always improving Natural Language Processing and
Domestic AI and Emotional Involvement. Design Perspectives.

Generation (NLP/G) and Computer Vision (CV) to detect and respond to emotions accordingly. (ii) As soon as the AI system connected to the activity house will be installed in people’s smartphones, it will unobtrusively monitor what happens to the user by accessing the device microphone, calendar, email and messages. Thus, it can keep track of the daily routines and modulate organization and propositions accordingly. Once at home, in fact, the AI system will manage the time of the inhabitants to make them reach a preferred state of well-being, by proactively proposing positive activities as a conversational agent, and by following them through a system of environmental cameras. (iii) At least at home, people will not need to think about what to do, as AI knows it better. As an entertaining system for happiness, it could suggest relaxing with a yoga session after a tough day or to try a new recipe for a personal sense of fulfilment, and it can guide the inhabitants throughout their activities by warning them in case of wrongdoing and with visual supports. For the system to work, AI capability to learn and adapt over time to its users’ characters, lifestyles, aims, increasing skills and external events, is essential. (iv) People will find in the activity house a matching support: who likes being surprised will look forward to discovering in which kind of activity they will be engaged in, while planners will see everything perfectly settled with no efforts. No wasting of time will bring to frustration: AI will allow making the most of it. (v) As a bespoke system that enables and encourages people to live an active and meaningful domestic life, it will prevent them routine organizational matters, becoming indispensable over time.

3.5 The hedonic house

Literary reference. In the hedonistic tradition, life is a quest for pleasure for pleasure’s sake, while negative affect is avoided (Deci & Ryan, 2008). This kind of well-being is ephemeral in nature. As demonstrated by the treadmill metaphor (Brickman & Campbell, 1971), the constant pursuit of increased well-being always returns to hedonic neutrality: positive and negative feelings provoked by a change of condition do not last forever, and people get used to them. Like rats on a treadmill: they keep running, but their condition will never change.

SFP. (i) In addition to bring pleasure, the hedonic house should be attentive to what happens inside and self-sufficient, not to bother the owners in any way. Thus, CV, NLP/G, and AI applied to robotics seem a perfect fit. (ii) Home appliances would be designed to autonomously perform their duties, and to create pleasurable sensations. (iii) The house will be filled with appealing and intriguing objects, and their functioning will be an enjoyable event. For instance, a laundry machine, directly linked to the wardrobe, could autonomously manage dirty and clean laundry, deciding when to do the washing or refreshing clothes. While in operation, it will give off a fresh scent, both to please people with positive sensations and to communicate its operational status. To facilitate the autonomy of the appliances, the space will be appropriately configured, and a control room will host the necessary equipment for the autonomous updating of self-sufficient machines. In fact, as soon as people get used to their functions and positive elicitations, these will evolve, adding new functions and positive feedbacks, involving also physical modifications. (iv) Then, the house will be a personal paradise, completely at the service of its inhabitants. It will shelter
people from mundane negativity while functioning just to convey pleasure. The only thing people will have to do when they need something will be to push the right button. (v) As the next frontier of consumerism, it may create addiction.

3.6 The eudemonic house

**Literary reference.** In contrast with the previous one, Eudemonic Theories focus on living life in a full and deeply satisfying way, pursuing personal development and meaning (Deci & Ryan, 2008). This conceptualization does not imply that happiness coincides with only positive emotions, instead it considers well-being not as an outcome or end state but as a process of fulfilling or realizing one’s true nature. To better define the characteristics of an eudemonic life and identify its key elements, different theories have been elaborated, such as self-determination theory (Ryan & Deci, 2000), well-being theory – PERMA (Seligman, 2011), or the six dimensions of psychological well-being (Ryff, 1989) including, for instance, self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life and personal growth.

**SFP.** (i) The eudemonic house will be the refuge to find well-being in the most meaningful dimensions of life. Acting like a conscience, its relationship with people should be quiet and discreet. In this respect, an AI system linked with sensors to perceive human beings and enhanced surfaces to communicate with them will constitute the basic technological equipment. (ii) To make the system flourishing is a proactive and shared perceptual (Marti, 2010) behavior, i.e. when the house detects the presence of a user, it should manifest its interactive intention and start it without being prompted. (iii) The eudemonic house will be a safe place to improve one’s psychical and emotional health. The AI system will – more or less directly – assesses its inhabitants’ levels of psychological well-being. Any surface in the environment can be a spot for communication: portraying questions, making suggestions, and instilling reflections to increase the personal values that mostly require an intervention. The interaction is smooth and subtle, and it depends on the user whether to embrace the cue or not. Impositions will not be allowed as without voluntariness, involvement is impeded. (iv) People living in the eudemonic house will learn to advocate their free time to meaningfully improve themselves and their lives, gradually reaching a complete sense of personal fulfillment. (v) Despite its pervasiveness, too much freedom may cause users to ignore the system’s inputs, as it happens with apps notifications.

4. Discussion

As anticipated, SFPs have been employed as theoretical experimentation to infer useful insights that could guide future design inquiries. Indeed, the scenarios are deliberately exaggerated to easily bring out the main features of the underlying psychological theories as well as the main critical points and interesting possibilities. Of course, they have the limit of being highly subjective, as they are the result of the authors’ brainstorming activity. Though, our intention is to initiate a discussion, oriented to focus the attention on the topic and to open a debate in the design community towards concrete and viable solutions. A possible
outcome of this work could be submitting the SFPs – with no design clues – in didactic contexts or workshop involving scholars and professionals to further advance the discussion.

In particular, the illustrated scenarios led us to three levels of considerations.

**Design-driven considerations.** From a design perspective, what emerges is that a cross-disciplinary approach is powerful to both address topics with more meaningful insights and to trigger creativity. Unconventional starting points for the discipline can lead beyond the borders of the absurd, but also suggest interesting directions. Maybe similar exercises can be developed changing the baseline references (a classification of AI possibilities could be one) to uncover different outcomes.

While, the main issue resulting from the development of SFPs in relation to domestic AI is the relevance of spatial dimensions. In all the scenarios it affects the entire environment somehow, as it seemed to be the most natural and consistent way to respond to the brief. Otherwise, confined in a single device, AI would not exploit its full potential.

**Human-driven considerations.** The overemphasized scenarios also reveal several issues related to the human sphere. They immediately raise ethical and ontological questions like privacy, sustainability and the role of sociality – both from an interpersonal and a collective point of view – that should be addressed even before designing, as regulators are trying to do. A further reflection involves the meaning of AI as part of domestic life. Self-determination theory (Deci & Ryan, 2008) sustains that the three universal psychological needs to satisfy for our well-being are: autonomy, competence and relatedness. Yet, is not AI aiming at the opposite? If we will rely on it, we will lose control over many things and even unlearn some basic tasks, while it is unclear how relationships could be improved. Evidently, fulfilling one request has multiple downsides and a balance has to be found.

**AI-driven considerations.** AI-enhanced products or systems are not like any other predetermined object, and this is a matter we must learn how to deal with if we want meaningful experiences. Then, understanding how this technology can affect interactions, especially long-term ones, is essential.

Additionally, as intuitively suggested, both emotions and AI are multifaceted and complex domains to work with, then solutions cannot be simplistic, and a comprehensive approach is needed. In fact, in the scenarios, a univocal approach was often limiting the possibilities of the AI, while summing up different psychological and design perspectives could enrich the experience.

Eventually, if AI is going to be implemented exploiting its full potential, it will radically change the paradigm of people’s life. Then, how can design drive the transition towards a beneficial outcome? Right now, it is a very open and debated question, concerning experts from different fields – i.e. Beneficial-AI movement (Tegmark, 2017) – and the design community really needs to contribute.
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Empowered by Code, to act in real word

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Abstract | Learning code is nowadays a common practice in many academics design curriculum; formal languages are probably the best “production tool” for creating parametric objects or interactive environments as Webs, Apps, immersive experiences or Data Visualization. This paper will explore the boundaries between analogical and digital world – illustrated by a few case studies – and will presents the results of a short summer workshop on generative design – for a non-visually skilled group of students – to underline the role of creative coding as an effective educational tool in Design.

KEYWORDS | CREATIVE CODING, DESIGN EDUCATION, PROCESS, IOT
1. Coding and education

Educational use of coding is almost as old as coding itself. There was a time when the word “computer” referred to people who computed – before it was applied to machines that did the same; at the beginning both, people and machines, manipulates numbers to obtain ... others numbers, until we realised that almost every piece of information can be represented as number (Alpaydin 2016); this was probably the mayor driving force in computing technologies and led us to the technological, social, industrial and cultural process of what we know as “Digital Media Convergence”. Nowadays, in an “internet of things” (IoT) scenario, this ability to “calculate” is spread among connected devices of any kind and sort. As Nicholas Negroponte predicted (1985), we are very close to a time where every single light bulb will have it’s own IP address.

Educational us of coding has a lot to do with both aspects: the ability to operates with almost any (digital) media and the capability of bringing the results to a tangible environment. This approach appears since the very early examples of educational programming language like Logo - the language developed in 1967 by Wally Feurzeig, Seymour Papert, and Cynthia Solomon at “Bolt Beranek and Newman” research labs in Cambridge, Massachusetts. One of Logo’s key futures was the ability to draw using a method known as “Turtle graphic”. Developers soon realised that kids were uncomfortable with the traditional way of drawing used in computer graphic – a cartesian space where X an Y axes have a fixed point of origin – and envisioned a different technique, much closer to the natural way of holding a pencil and moving it on a paper. Drawing using a computer became a matter of “driving” a “traveling pen” plotter (the turtle) steering, counting steps, rising and dropping the pen to the paper.

The educational value of coding come essentially from the versatility of computing technologies. As as Seymour Papert (1980) pointed out: “[computing] can take on a thousand forms, can serve a thousand functions [...] and appeals to a thousand of tastes”. A great example of the versatility of modern educational programming languages is Scratch, the event-driven visual environment developed since 2002 by the MIT MediaLab. Thanks to its block-based approach, Scratch brings the ability to create drawing, games, stories, animations and on-line applications – using techniques as physical computing, remote sensing, computer vision or music synthesis – to kids, without the hassle of writing the right syntax, focusing entirely on logic (and fun).

The following case-studies are aimed to illustrate why coding should be considered not just as an effective educational experience, but also as a powerful didactic practice in Design curriculum.
2. Focus on the process

Creative coding is not just an easy way to create many visual variations; drawing by algorithms moves the designer’s attention to the process that produces shapes rather than on the shapes themselves. The use of a formal language to create a visual output – as in generative visual design – is somehow unnatural but it’s an interesting training on rules, proportions, spatial distribution and color spaces. In a brother sense, is a way to work on visual issues at a more abstract level.

“Software Structures”, the serie of generative algorithms created by Casey Reas with Jared Tarbell, Robert Hodgins, and William Ngan in 2004, exemplify very well how a simple geometric behaviour is able to generates a surprising visual result (Reas 2004). “Structure #003”, for instance, is a surface generated by 100 medium to small circles moving at the same slow rate and bouncing at the edges during a given time. The pattern is created by drawing straight lines at the intersections of the circles frame after frame. When the process is over – or even while is taking place – is quite difficult to infer the generative behaviour just by looking at the final result.

Coding is an efficient manner of exploring iterative shapes, like fractals, that are at the very heart of several natural processes. In “drawing a tree”, Bruno Munari (1978) suggested a mix of drawing techniques and analogical models for a better understanding of this simple recursive structure. Cutting a strip of paper in 2,4,8 ... branches, and folding them on a table with different angles, reveals the key elements that may be reproduced on the screen by loops in code. The tangible paper model also allows to easily detect which magnitudes are
more suitable to be converted in variables in order to produce a range of variations from the same abstract archetype.

Figure 2. Bruno Munari - Disegnare un albero.

Moreover, coding is probably one of the easiest way to simulate complex systems and to observe (or create) emergent properties. Simple object oriented basic coding techniques, like those proposed by Daniel Shiffman in “The nature of code” (2012), have empowered a whole community of creative not-so-experts coders. One of the nice side-effects of working is the support of a strong collaborative community and, as the evolution the Open Source Software movement remind us, communities (as Universities should primarily be) have a key role in the creation of common goods and in the development of a collaborative culture (as Design have sometimes been).

Design is not always a matter of applying ready-made recipes or predefined protocols to a given brief. Working on the process, rather than on the final proposal, is often a good method for a more strategical approach in the quest for a suitable design solution.

3. Mixing media

Every digital media have its own editing tools; most of the proprietary and open source applications of this software ecosystem allows user to merge different supports and create standard multimedia contents. Aside from desktop applications, coding languages are still one of the most common interfaces for the creation of interactive environments, even if a significant part of the design community (including some interaction designer) is still trying
to avoid this field and prefer to let tech specialists to craft and bring to digital devices their interaction’s blueprints. Truth be told, most production workflows in the digital media industry are designed according to this tayloristic approach. However, creative coding solutions, like Processing, OpenFrameworks, Vvvv ... and so on, allows coders to work at the roots of digital information, much closer to multimedia bits, at a level that desktop and web applications – optimized for production tasks – can not reach.

As an example, the Colla Castellera de Madrid used a small dataset of coloured dot samples for the visual identity of an event, published as printed materials, web animation and a short motion graphic’s video. “Human castles” (Castells) are a popular traditional activity in Catalonia, Balearic island and the Valencian Community; the construction of a 10 floor human castle may involve up to 700 people – most of them at the ground level disposed in concentric circles around the tower. For this reason, the metaphor of an ordered cloud of coloured dots is often used in human castle’s iconography. The main illustration used for the visual identity of the “Festa Major del Cercle Català de Madrid” is a detail of a human castle represented as a very low-res dot sample, in a kind of a pointillism image (not so far away from what you can get with a pointillize filter in any image editing software). The difference here is that the data obtained in the dot sampling process (x, y, size and color) were “stored” in a json file used to create both, the final static svg illustration and a motion graphic sequence that showed the inbetweening of ordered and unordered distributions of the dots.

Designers are increasingly called to operate and design on non-standard outputs. As part of the refurbishing of the Madrid’s headquarter of Abanca – a mid-size Spanish bank – a custom led sculpture have been installed on the façade, behind the balconies, at the corner
of the building. This four floor height custom lighting device acts as a very low-res big screen and is made of 900 lighting elements hanged in a 30 cm depth and 3 meter wide space. The irregular distribution of the lighting elements, and the distance between them, allows the device to display only abstracts black and white patterns. The lighting effects are generated by algorithms that converts a musical pattern, like J.S. Bach’s Goldberg variations, into geometrical shapes. The result is a kind of “digital synaesthesia” that take advantage of a well-shaped musical signal as a source for a consistent, but still unpredictable, visual output on a silent façade.

4. The IoT scenario

In nowadays IoT scenario, coding enables designers to take controls on simple (connected) objects to creates complex choreographies.

“A million Times”, the kinetic sculptures created by “Humans since 1982” represents a good example of this approach. In this ongoing project, first exhibited in 2013, Bastian Bischoff and Per Emanuelsson - who met as postgraduate students at HDK Goteborg in 2008 - played with the hands of multiple analogue clocks, ordered in a matrix, to create visual effects that “unveils hidden figurative qualities without denying its primary purpose”.

![Figure 4. Objectifier - by Bjørn Karmann.](image)

Things become even more interesting when the connected objects can acts as sensors or actuators. The creative framework of solutions known as “physical computing” allows engineers, programmers, designers and hobbyist to push computer interaction far beyond
mouse, trackpads and screens. Prototyping this quite new field of user tangible interactions is now an attainable and affordable task thanks to microcontroller kits – i.e. Arduino – designed to translate analog input to a software system and / or control electro-mechanical devices such as motors, servos, lighting or other hardware.

On this path, “Objectifier” – by Bjørn Karmann – represents an interesting simple proposal from a promising radical premise. Developed in 2016 as graduation project at the Copenhagen Institute of Interaction Design (CIID), Objectifier reverse the traditional approach of ergonomics and affordances where the user has to learn how to use an appliance. The device acts as a smart interface and is able to grab user’s gestures that can be assigned to specific functions of a given object as, for instance, a lamp. According to its author: “Objectifier empowers people to train objects in their daily environment to respond to their unique behaviours”. A video camera, a few computer vision algorithms and a little bit of artificial intelligence are the main ingredients of this solution that let the user to teach its lamp witch gestures will be used to switch or dim the light.

Another interesting proposal the involves computer vision and artificial intelligence is “Water Machine Control” by Sergio Galán. The main purpose of this artistic installation was to drive public attention toward the algorithms that control video surveillance systems and their social and political bias. The proposal was developed in 2016 as part of a workshop on technology in public spaces held in Zaragoza (Spain) at the Etopia Art Center. A swiveling water gun, installed two meter above the floor in a public garden, was controlled by a face detection algorithm and pointed straight at the face of people who passed by. The coloured toy followed and threatened the pedestrians but shot a drop of water only when a certain kind of face – namely young males with beards – was detected. The installation made use of an available and quite sophisticated cloud API that allows not only face recognition but also an accurate segmentation of facial traits.

5. Artificial Intelligence and Machine Learning

The unprecedented availability of digital data we are experiencing in recent years is setting a new paradigm for what algorithms can do, the way they do it and – more generally speaking – our definition of artificial intelligence (AI). This evolution is having impacts even in creative fields and, as we have seen, is already part of the design practice.

Until very recently our idea of AI was associated to smart algorithms, like a chess playing one, a logical structure that contains all the information required to efficiently perform a given task and that could be adapted to achieve other similar duties. Machine learning (ML), a branch of AI named by an essay of Arthur Samuel (1959), operates in a completely different way and behave as a dumb analyst of a lot of samples to perform very specific assignment. Machines can be trained to complete one single specific task (like recognising faces in a photographic image) without using explicit instructions, thanks to statistical
models that simulates neuronal networks. ML is the perfect match of XVIII century Math – like Bayes theorem – and III millennium abundance of digital samples.

For creative coders, training a neuronal network of data samples can be much easier than learning the logical skills of a good computer analyst. Open source digital libraries – like Tensorflow – have been already widely used in arts and design. Python libraries as “Magenta” have successfully implemented Tensorflow for music and image data training in order to generates new original content. “Performance RNN”, a model for polyphonic music with expressive timing and dynamics, is one of the best known Magenta’s outputs. As its authors claims: “[Performance RNN] ... is trained on the Yamaha e-Piano Competition dataset, which contains MIDI captures of “1400 performances by skilled pianists”. The model has no notions of harmony, melody or musical composition, the only thing it knows is that skilled pianists press piano keys over time according to certain patterns. Results are astonishing enough to suggest a debate and eventually reconsider certain assumptions about creativity.

Code can guide and assist designers – and design students – to figure out unexpected solutions and to give new answers to contemporary or traditional design brief. From an educational perspective, formal languages may offer to the academic community a new vantage point for the observation of design processes, as illustrated in the last section of this text.

6. A summer workshop on coding and generative graphic design

NeoLocalDesign (NLD) is an annual event organised by DADU (Dipartimento di Architettura Design e Urbanistica - Università degli Studi di Sassari) aimed to re-think design as the vehicle to combine tradition with innovation and rediscovering local knowledge as a major asset. In its 2018 edition, NLD hosted in Alghero – in the north of Sardinia – a summer workshop on coding and generative graphic design. The goal was to create a visual identity for a small network of local archeological sites using generative techniques.

6.1 On generative visual identities

Generative techniques have already successfully been used in visual identity probably because they are the equivalent – in a “design systems” approach – of a predefined collection of static signs in a classic “Corporate Identity Manual”. Generative visual identities are not intrinsically better than more traditional ones, the reasons why they are sometimes implemented are – most of the times – rhetorical and concern poetic rather than communication performances.

While explaining their 2011’s proposal for the MIT Media Lab - The Green Eyl Studio team declared:
“The 45,000 possible variations [...] represent what the Media Lab constitutes: creativity, diversity and reciprocal inspiration. The design is based on three geometric figures that are rearranged and coloured for every application. Each figure symbolizes the contribution of an individual towards the collaborative process; the entire form stands for the result: a continuous redefinition of what media and technology could be today”

None of these reasons applied to our case; from our perspective the network of archeological sites represented a great chance to work with an awesome iconography of strong ancient signs.

6.2 On ancient shapes

Workshop attendees had little or no formal background in visual communication and probably they wouldn’t be able to produce, from scratch, original shapes of the same graphic quality; nevertheless, they were actively involved in a real design experience. Ancient signs have been efficiently adapted to contemporary logos by professional designer in the past. Back in 1975, Pino Tovaglia, Bob Noorda, Roberto Sambonet e Bruno Munari converted the “camunian rose” – a symbol from the iron age – into the logo of the Lombardy region.

Figure 5. Workshop’s sketches.

Alghero’s network of archeological sites preserves heritage from the Nuragic civilization, that lasted from the 18th century BCE (Bronze Age) to 238 BCE, when the Romans colonized the island of Sardinia.
6.3 Activities

Workshop activities were organized in three main blocks: a general introduction on generative visual identity, a short hands-on training on a coding platform and the design experience where students worked in three small groups, one for each archeological site: Palmavera, Santu Pedru and Anghelo Ruju.

After a preliminary iconographic research, each group selected the ancient mark they were willing to work with, two of them – the silhouette of a bull head and a horn motif – where already a “family” of images composed by several specimens carved on the stone, the other one was the aerial view of the archeological site of Palmavera. Groups were asked to observe and redraw a streamlined version of their mark paying attention to geometrical proportions and to the physical arrangement of different elements. By doing so, they were forced to simplify details and to focus on qualitative properties of the shapes. Thanks to this analysis they were able to define a set of rules, a graphic procedure, for the reproduction of the simplified mark and its possible variations; with some external help they were even able to formalize their procedure as a generative code and starting playing with it. One group, the one working on the horn motif, decided to explore several ways of repeating the original shape – changing size and orientation, the other two prefers to keep one single element at the time.

6.4 Conclusions

The overall experience was not just about coding but the initial assumption of working with generative code shaped the design process and implied an analytical and heuristic approach.

The educational value of creative coding in design depend largely on our personal appreciation of what Design pedagogy should be. We all know that is probably not a matter of “telling people how to do things” but rather to prepare a next generation of design professionals for a never ending training on the search for (several) methodologies, experiences, dialogues and conceptual references that may bring them to an appropriate practicable answer.

References


Empowered by Code, to act in real word.


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Exploring Digital Inequalities: How Welfare States are disappearing behind an AI.

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Abstract | This paper draws on the literature around the so-called third wave of digital inequalities (Daly, Devitt and Mann, 2019), which moving beyond the concept of digital divide, explores deeper inequalities that platforms and algorithm are generating in our societies. As digital platforms and algorithm are increasingly used to plan and deliver welfare programmes, it has been argued that these new technologies are in fact creating what Virginia Eubanks defines as the new ‘digital poor houses’ (Eubanks, 2017). The paper will start by introducing the field of digital inequalities and will then draw on ethnographic field-work and policy examples from the UK Welfare Services to present the state of the art on the use of digital platforms in this field. and highlight some of the critiques that have recently been raised. By posing into question the emergence of a technocratic culture of public services, the paper also aims at outlining possible ways in which design can play a role in this context.

KEYWORDS | DIGITAL INEQUALITIES, SOCIAL ENGINEERING, TECHNOCRATIC CULTURE, WELFARE SERVICES

1. Introducing the Field of Digital Inequalities

The field of Digital Inequalities could be defined as characterised by three waves of scholars, activists and rights that have shifted the focus and the way we define inequalities in relation to the digital realm in a quite dramatic way. The so called ‘first wave’ was mainly focused on the digital divide and discourse on information poverty. Initially developed in the 1990s this way of framing inequalities put the focus on the differences between Countries (and later within Countries as well) on those who had access to a digital device (and namely usually a
computer), access to the internet and therefore access to information and data. The digital divide was through these discourses depicted in terms of ‘have’ and ‘not have’ (Jurich, 2000).

The ‘second wave’ is very much linked to the first, but starts from a different understanding of the complexities of the question of access, which were deployed more simplistically in the first definitions of the digital divide. Questions of access, for instance, become understood as question of engagement and outcomes as well, as it becomes evident that having a computer and internet connection is not enough in order to give everyone the opportunity to engage with online content and services. Different skills and resources would be needed in order to face a divide that becomes more nuanced, as engagement is understood as something that does not just happen once in time but needs to be sustained as well in the longer term, and what we achieve as a result of that engagement also comes into the equation. Through these lenses, we could start developing a more sophisticated understanding of digital inequalities through the prism of what has been defined an Access Rainbow (Selwin, 2004) which highlights different shades of inequalities.

The so called ‘third wave’ is more typical of our current times, as scholars and activists shift the focus away from the digital divide and raise issues of how the use of data is impacting stigma, as for instance in the use of digital public services. This is not a shift of little consequences, as the discourses have moved from devices to platforms and data; from the question of how one can use the digital resources available, to a question of how our data are used and what they do to us.

Whilst the first wave was clearly built on a techno-enthusiastic paradigm - which framed the being out of digital connectivity as missing out of the advantages of the digitalisation - the third wave, very differently is borne out of the critiques of what has come to be considered as an opaque, unregulated, and un-contestable system of digital tools and data (Daly, Devitt and Mann, 2019). Central to the discourses of the third way, especially when digital tools are used in public services I would argue, are questions of digital rights and data justice, as citizens using public services are made visible, represented and treated differently as a result of their digital activities and records (Heeks and Shekhar 2019, Taylor 2017, Arora 2016).

Digital tools in Welfare Systems Technology for poverty management is what this paper and my practice are concerned about and I will move in the next section to introduce the field where I have been researching, which is the field of social and health services in the UK and specifically the field of mental health services.

2. The Case from the UK: Mental Health digital by default

A recent UN paper formulated strong critiques to the UK Government, advancing the accuse of making the “British welfare state (...) gradually disappearing behind a webpage and an algorithm.” (UN, 2019). This paper refers very much to the current situation in the UK, where a fully automated and ‘digital first’ system of welfare services has been designed and
delivered with the intention of improving the effectiveness of welfare services, avoiding waste of resources through optimisation of data and information flows.

In the UK, the Voluntary Community Sector (VCS) contributed £17.1bn to the economy in 2016/17, representing around 0.85% of total GDP (according to the UK Civil Society Almanac 2019). As denounced in a paper from 2016 (Pierri and Warwick), the Government public services reform (HM Government, 2010, 2011) has significantly impacted the mental health system: reducing its costs, aiming to shift the demand away from acute services and into prevention, delivering care that focuses on recovery and self-management instead.

Community mental health services in the UK are those services designed and delivered within the community, which provide non-medical and alternative interventions (e.g. talking therapies or alternative therapies). In the context of social welfare relationships, a strong tradition exists of mental health users’ movements, borne out of collective action and independent from any invitation or encouragement by public officials or other organizations. These movements, and the mental health organisations which were organised as a result, aim at enabling people to have more control over the issues that affect their lives. Most of the evidence collected by the UN report comes in fact from these sources, as well as larger mental health and social services organisations, across the country.

In January 2019, the British National Health System (NHS) published the NHS Long-Term Plan, which outlined ambitious target for health care service delivery in the next ten years. Mental health, for its high-cost on the health system, figures among the seven clinical priorities that are identified in the document. Without going in the details of the plan, what is interesting to mention is that “Digital technology underpins some of the plan’s most ambitious patient-facing targets.” (Charles et al 2019). This should not take anyone by surprise, who has been working in the past 10 years in health and social care in the UK. It was already in 2012, in fact, that the UK Government started the nationwide experiment to make public services ‘digital by default’ (HM Government 2012). In 2016 the Government made a further step ahead and made a clear commitment in that direction by stating in its Transformation Strategy (2017): “We will transform government services and make government itself a digital organisation.”.

My work mainly developed in the field of health and social-care and particularly in the mental health services. I did not start studying the digital field or the digitalisation processes of Government first hand, but I got interested into this topic as services in health and social care for people who were experiencing mental health distress were increasingly and rapidly being digitalised. Drawing on Virginia Eubanks (2018), we could see the field of welfare services as the field where social experiments with digital tools have taken shape first, that will be expanded to other groups and the general population later. This situation, as this paper wants to illustrate, raises important questions of equality and rights as new modes of surveillance are deployed through Welfare Systems Technologies and algorithmic-led predictive models are introduced to predict social deviance and poverty. This is a long-term trend, which Eubanks identified as started back in the 1970s Welfare models in the US: “They commissioned expansive new technologies that promised to save money by
distributing aid more efficiently. In fact, these technological systems acted like walls, standing between poor people and their legal rights. In this moment, the digital poor-house was born.” (2018, p33).

Digital platforms and algorithms used in public services, although not responsible for creating stigma and social exclusion of those who are most marginalised, can supercharge discrimination by removing the human factor from the process of managing the welfare system and therefore reducing empathy and compassion in this area. Moreover, has been argued, through the digitalisation of the welfare systems more marginal groups end up being increasingly subject to higher level of data collection and violation of privacy (Eubanks 2018). The UN paper (2019) has had the incredible merit of bringing the topic of algorithmic welfare services on the radar in the UK and beyond, as the British example – I would argue - raises wider questions and implications that would apply to other welfare systems around the world. I would like to use the British example to build two broader reflections on the impact of design in shaping our digital public services and the wider public space: first on the role of design in programming the future, second by analysing the theme of stigma in design.

3. The Role of Design

Driven by a culture of ‘data fundamentalism’ (Crawford, 2013) computational power is introduced by design in public services, behind the assumption that complex issues can be solved by getting the right information, at the right time, to the right people. This is based on a culture of technocratic models of public services, which is spreading in different countries and is developing what Bucher (2018) has defined a ‘programmed sociality’. This concept, rather than creating a vision of technological determinism, aims to shed light on the politics of ‘categorisation’. Algorithms, in fact, create categories that end up programming our sociality and this, I would argue, is especially true in the welfare system.

3.1 Future orientation

In one form or another, the future has always been at the centre of interest for design as the discipline that more than others deals with issues of becoming and the giving shape to the not-yet, which is the future. As John Urry reminds us, whether it was by matter of divination, through the study of the past events, and the legacies of our ancestors, humanity has always been busy trying to guess, understand, preview and control the time of the ‘not yet’ (Urry 2016). Whereas in the earliest approaches to the future, this was supposed to be falling in the domain of Gods, as something humans could perhaps get to know but never to change; with the crisis of Christianity in the West, and the rise of industrialisation later, this attitude started to change, and women and men began to think that they could forge and make the future the ways they wanted, or at least try to do so. As Barbara Adam reminds us (2010), this change in ownership of the future, from Gods to humans, also saw the emergence of new kinds of specialists, who knew how to trade and shape the future better than others.
From fortune-tellers, to astrologists and priests, to the new experts who go under the identity of economists, technologists and, I would add, designers, many different actors and professions have claimed for themselves a specialization around the future at different points in history.

In our current times, I would argue, we are possibly witnessing a new shift in the governance of our future. Complex, emergent, nonlinear, futures had become at one point to be perceived as impossible to plan, even from the perspective of more traditional future studies (Inayatullah 2013). With the introduction of big data and algorithmic decision-making, futures seem to have gone back to the time of the Gods. Human can do very little to shape their futures but they can only look into the future scenarios that algorithms are depicting for them. As society becomes obsessed with questions of prediction, risk-management and control algorithms are left to take the most important decisions about our futures. As Philipp Alston stated (2019) in the special rapporteur on extreme poverty and human rights:

“Systems of social protection and assistance are increasingly driven by digital data and technologies that are used for diverse purposes, including to automate, predict, identify, surveil, detect, target and punish. But the very real risk is that we are stumbling zombie-like into a digital welfare dystopia. Such a future would be one in which: unrestricted data matching is used to expose and punish the slightest irregularities in the record of welfare beneficiaries (while assiduously avoiding such measures in relation to the well-off); evermore refined surveillance options enable around the clock monitoring of beneficiaries; conditions are imposed on recipients that undermine individual autonomy and choice in relation to sexual and reproductive choices, and in relation to food, alcohol and drugs and much else; and highly punitive sanctions are able to be imposed on those who step out of line.”

The question of the future, which is ultimately I would argue a question of people’s agency, is one that is often overlooked and which I believe designers involved in the field of Welfare Systems Technologies should embrace. Beyond the immediate breach of privacy and negation of rights that is happening through the digitalisation of welfare services, forms of social determinism are introduced, which aim at building algorithmically-led predictive models that can tell us with increased precision – or at least this is what they claim - how people who are in charge from social services might behave. These models built though the use of predictive variables are potentially eternal, as data collected about social benefits and health care records will last for very long time, and risk depriving the subjects involved of their right to have and build a future for themselves which is open to infinite possibilities, also of turns that might seem unpredictable now. What will happen to them – and potentially this could be extended through data triangulation to their friends and families – is predictable, therefore predicted, hence it becomes real. If design is about the opening of possibilities – as so often predicated by scholars and practitioners of design – what these algorithmic-led predictions do to designers (and vice versa) would be an area to further explore.
3.2 The Disappearing Human: are we Designing for the Algorithm?

In this paper, I propose to frame the design of the digital tools and platforms for welfare services as a terrain of struggles for social justice and equality of treatments. As an increased number of designers are employed in the new digital health and social services, issues should be raised about the role they perform and the assumptions behind their design choices. Designers involved in the design of Welfare Systems Technology should consider the fact that “Those designing AI systems in general, as well as those focused on the welfare state are overwhelmingly white, male, well-off, and from the Global North. No matter how committed they might be to certain values, the assumptions and choices made in shaping the digital welfare state will reflect certain perspectives and life experiences.” (Alston 2019, p4).

The data-driven approach that is built in these technologies through machine-learning processes risks to ignore a number of human factors that are the core values on which welfare systems have been traditionally built, and namely: dignity, empathy, respect and social justice. As Meredith Broussard reminds us in her book, whilst law and institutions are made to take care of things that societies believed to be important, data–driven decisions rarely reflect these values in their functioning: “Part of the reason we run into problems when making social decisions with machine learning is that the numbers camouflage important social context” (Broussard 2019, p115).

Designers could play a key role in bringing these social and human contexts back into the way machine learning decision making is made. This is a question of central importance and where designers should not remain ambivalent. If it is true that design could be understood as a ‘double-headed monster’ (Borka as cited in Bieling 2019:5) – one side powerful and progressive and the other side dangerous and potentially conservative – we should be intentional in searching for ways to maximise one side (the powerful and progressive) over the other, for instance by exploring how could design take an explicit political stance in this new field of designing for the Algorithm. It might be worth clarifying that here I am not referring simply to more mainstream human-centred design approaches, as in these more consumerist instances users are definitely not understood as political subjects (but perhaps as subject to). In these instances, in fact, users are considered central only to the extent to which they can support the design process to improve service efficacy and users’ satisfaction. I am rather referring here to a humanistic-centred approach that considers the subject as a democratic subject (the subject of rights and respect).

Following from Anja Bechmann and her work in the field of human rights, I believe designers should focus “not accounting for the algorithm itself as a standalone solution, but on social values that have been encoded into the algorithm directly or indirectly as (political) choices made by developers.” (2019, p87) and I would add designers as well.

3.3 Stigma and the Design of the Digital

Stigma is a socially constructed, relationship-specific attribute that exists in a social context. Actors become stigmatised when they have an attribute that devalues them in social situations. This attribute and the consequent stigma would be differently constructed in
Exploring Digital Inequalities: How Welfare States are disappearing behind an AI

different contexts and according to different identity traits. Once an individual – or a group – is affected by stigma from other groups in the wider society, this process impact negatively on life opportunities of those individuals and groups, including health outcomes, housing opportunities, academic achievement, income, and the likelihood of criminal involvement. We could therefore say that stigma is a powerful and complex force that produces inequalities. Link and colleagues (2001) identified four type of these inequalities: (1) direct person-to-person discrimination; (2) discrimination that operates through the internalization of negative ascriptions among stigmatized individuals (i.e., self-stigma); (3) interactional discrimination involving the perceptions of stigmatized individuals; and (4) structural discrimination. We should perhaps start thinking about adding an additional type which will have to do with the design of the algorithmic decision-making in the welfare context.

Stigma is a causal process, which develops through the act of labelling individual or groups, with labels that have of course a negative stereotype attached to them. This labelling exercise causes exclusion and discrimination, through the attribution of a low status (social, cultural, or in other domains) to the person or the group affected (Link and Phelan, 2001).

Working in the field of mental health, the question of stigma is a question I have faced many times and one which requires designers involved in the field to adopt a more self-aware approach, in order to make visible the layers of identity, discriminations, and power structures that interact when somebody is identified as a person with ‘mental health problems’. We shouldn't forget that within medical models of mental health, it is usually the culturally dominant group that gets to define what the healthy, appropriate ways to conduct oneself are, and do so in accordance with their own norms and practices. The field of design that deals with digital mental health services I would argue, therefore, offers a stark insight into the dynamics of categorisation that are inscribed in the algorithms and that influence stigma and inequality in turn.

As the design researcher that collects and present insights based on personal stories that will end up feeding the technical design and development of the algorithm within these Welfare System Technologies, one has a great power in choosing how to represent the people one has talked to. Acquiring more awareness of the language of discrimination, thinking carefully about the chosen visuals representations to use, finding ways to convey the diversity without reinforcing existing stigma and stereotypes would be the skills and capabilities that the designer working in these contexts should sharpen.

On an even more basic level designers could do much more to avoid still existing issues of digital divide in this area. These issues could generate absolute inequalities like “When (people) are forced to use digital channels for which they have no access or skills, they will be excluded in absolute terms.” (Van Dijk 2020, p112). In this instance the concept of second class citizens is constructed, as in a digital only scenario the only option left to those who have no skills and access is to be able to access services through the help of others (in the case of welfare services this happens predominantly through the support of mental health organisations).
4. Where next?

Technologies of poverty management – as Eubanks defined them (2018) – are as we know not neutral, since they ultimately reflect back to our wider society our own most intimate prejudices, stigma and fears about questions of poverty. As digital tracking and data driven decision-making are becoming predominant in public services, questions of social justice and human rights should be addressed by everyone designing for these platforms. This is particularly true of what have been called “low rights environment” (Eubanks 2018, p12), which are the fields of social and health-care services.

Issues of transparency and accountability have been raised on several levels, starting from the UK Government’s purchasing system of digital tools (Black and Safak 2019), going to evaluate potential social worker surveillance (Devlin 2017) and algorithmic decision-making. Recently, a Dutch Court has made a key decision affirming that the automated surveillance system developed for detecting welfare frauds (something similar to what has been recently developed for the UK as well) was violating citizens’ human rights. The organisation Human Rights Watch which has been monitoring the Dutch case and other cases of human rights violation within digital welfare systems has many times denounced the lack of transparency and consultation as one of the main issues with the Welfare Systems Technologies. I believe this is another area where design could play an important role.

As in the machine-learning community’s concerns around issues of inequalities and accountability have been already raised (Broussard 2019, p195), it is time in fact for the design community to do the same, and to interrogate its role within the UK Government and Departments, and specifically within the digitalisation process, more seriously.

I believe in fact that by focusing on these issues instead – and namely, the question of stigma, the issue of transparency, the human element and the role for public engagement and civic participation – design could play a very different role within the digital agenda of the current Government. It could for instance focus on an area which has been surprisingly overlooked so far, and which would bring forward the question of how to use these technologies to transform the welfare state for the better:

“Instead of obsessing about fraud, cost savings, sanctions, and market-driven definitions of efficiency, the starting point should be on how existing or even expanded welfare budgets could be transformed through technology to ensure a higher standard of living for the vulnerable and disadvantaged, to devise new ways of caring for those who have been left behind, and more effective techniques for addressing the needs of those who are struggling to enter or re-enter the labour market. That would be the real digital welfare state revolution.” (Alston 2019, p4).

The case has now been made, by the movements of those mental health service users who have been fighting against the conditions of services, by the many organisations advocating on their behalf, and recently by the UN Report as well. I think it is time for those designers...
involved in this field to start discussing whether and how to accept the challenge ahead and repurpose their role in Governments for the digital agendas, around Europe and beyond.

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From Decoration to Functionality — Research on smart accessories design in the Internet era

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Abstract | From primitive society, jewelry is born in functions, which were a kind of tool to protect people from attacking, by wild beast and other primitive. As society advances, the decoration property of jewelry has become stronger and stronger, which were ignored that jewelry did not have functionality by people. Over many thousand years, with the development of technology and the improvement of the Internet, jewelry combined with wearable technology has become a new form of functional jewelry that has unprecedented functions. Throughout following discussion and a large quantity of cases analysis, this paper discusses functional jewelry, especially smart jewelry, which is fashionable and functional, and solves some daily problems. It provides design directions and guidelines for future smart accessories design.

KEYWORDS | SMART ACCESSORIES, WEARABLE TECHNOLOGY, FUNCTIONALITY, INTERNET ERA
1. The Background of the research

1.1 Technology improvements promote the fashion industry

Over the last decades, technology develops, particularly fast, which can be described as a completely explosive leap. Nowadays, the Internet era is gradually mature and the digital information and industrialization is growing fast. It is said that the development of art and new technology is always supplemented and complement each other and help each other forward. Technology supplies technical support for the jewelry design. With the development of Internet, Internet of Things (IOT), cloud computing, Big Data, wearable technology and other information technology, the application of digital software, 3D printing, and intelligent wearable technology have greatly promoted digital accessories design. Technologies like 3D Printing, Rapid Prototyping, Rotational Moulding, Selective Laser Sintering, Sheet Metal Forming, Stereolithography, CNC, Laser Cutting and Acid Etching — a complete description of these can be found in the appendix — will be available through outsourcing, and with collective creativity will also be able to be applied to jewelry, with the possibility of creating new forms and finishes. Likewise, under the influence of fast paced lifestyle and the requirement on aesthetics from customers, it requires jewelry need add more functional and popular elements on modern jewelry. Therefore, the modern jewelry needs to be designed creatively to meet new requirements in the information age.

From 2012, it has been the first time for the fashion industry to embrace technology industry. Google glasses have aimed to high fashion and wearable technology has been a hot spot in both wearable technology industry and fashion industry since that time. After that, so many companies are all working hard to launch the product combining with fashion elements and wearable tech. Nowadays, wearable technology industry is gradually mature. Compared with the former wearable products that were made of plastic, silicone material and paid more attention on technical intelligence and male customers, the current wearable products are jewelry-based and fashionable those are attracted by female customers. The smart products based on fashionable jewelry form will become the next focus in a few years.

1.2 It is necessary for accessories from decoration to functionality.

In the past thousand years, traditional jewelry is mainly considered as the symbol of identity and a store of value. It was just belonged to the rich. Recently, the market sales of traditional jewelry made of precious metal has been declined gradually. The jewelry market is intensely competitive, serious and grave now. Accordingly, developing new product line, seeking a breakthrough for the brand and occupying competitive advantages on the smart accessories field are the only choice to face difficulties. Recent years, wearable technology has been a part of people’s daily life, improved people’s quality of life, and gradually became an essential thing in daily life. As a result, it’s a necessary trend from decorative jewelry to functional jewelry.

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1 Alba Cappellieri, INTORNO AL FUTURO (AROUND THE FUTURE), Marsilio Editori s.p.a., 2014, P24
1.3 The market requires innovative accessory products, both on aesthetics and functionality.

Design can lead fashion trend, and the science can create the future. Innovative design is produced. The monotonous product is far from satisfying the needs of consumers. Practical functions are no longer the only standard to be measured, but also novel styling, comfortable colors and the application of new technologies and so on. These factors have a great impact on consumer decision making. The customers from different social class, different cultural background, as well as different psychological needs have different demands. Nowadays, many companies have turned to tech and jewelry market, so that it forms a highly competitive market. Some luxury brands are aiming at cooperation between fashion and technology industry and continues striving to design new fashionable and tech-based products. As for fashionable wearable products, entering jewelry market is a necessity. I believe in the near future, with the development of science and technology, jewelry is not only a symbol of the status or beautiful ornaments, but also giving people more unique wearing experience. Meeting the functional needs of all aspects, helping improve people’s quality of life, and achieving the perfect blend of art, technology and science is modern designers’ duty.

2. Accessories with functions

2.1 Functionality of accessories in the past

Defending the enemy and protect themselves

In the past, from the ancient period, the jewelry is a kind tool to defend the enemy and protect them prevent from attacking by the beast. Later, this kind of tool had evolved a form of initial jewelry decorating around people’s bodies. Data shows that, besides the Karen’s lots of long neck collars, some neck accessories are to prevent the beast’s attack that plays a unique protective effect.

Decoration & Adornments

The world’s oldest Paleolithic ornaments, such as animal teeth, feathers, or stone beads have a pretty distinctive feature that are smooth, regular, compact and beautiful. These features further explain that the jewelry for making up have shown a kind of psychological motivation to attract the opposite sex. So the statement that pursuing beauty is an origin of physiological instinct is really scientific. The “beauty of the human body” function, which is evolved from this origin, is the most primitive function of jewelry. Decoration is the most important function from now on. From the simple shell beads worn by Palaeolithic hunters to the splendor of Renaissance goldwork and the sumptuousness of Art Nouveau enamels, the jewelry is always revealed in the importance of decorative function all the time. According to different cultures and the background of the times, the aesthetics and appearance of jewelry are different.
Showing status and keeping memory
People have always felt the need to transfer their sentiments to a symbol, which strikingly embodies their mystery and represents their eternal nature. For example, wedding ring shows the marital status, also people wear pendant as a necklace and usually put some photos in it for missing their friends and relatives. In the Song dynasty of ancient China, the ring is also a tool of imperial concubines showing whether during the period or not.

A symbol of identity
In primitive tribes, in order to show their power and ability, chiefs and warriors decorated themselves with objects that were easy to identify.

A store of value
The materials for making jewelry were mostly precious metals and precious jewels, so that jewelry could be preserved for many years. So most of the remaining jewelry has a high economic value.

Health care
In oriental culture, some gemstones, like jade, pearl, agate and crystal, has functionality of massaging acupoints and meridian as well as activating blood circulation. Some metal like silver, it has effect of sterilization. Wearing silver can absorb the toxic substances to prevent from wound infection. Moreover, wearing pearl necklace can make people feel good and pearls can also relieve the pain of neck. Non-stop swing can play the role of external application, resulting in a variety of natural substances absorbed by the skin.

Exorcise evil spirits and blessing
There are some mask-like jewelry that shows the role of exorcising evil spirits, being worn in a grand ceremony, carnival and other activities in China and the Europe. For example Chinese Nuo Mask, it would keep away from evil and bring good luck. In Asia, there are Nuo Masks, Tibetan Opera Masks, while in Africa there are masks of Baoule with animal-horn shape, Helmet masks of Yoruba. The type of mask and carving style is extremely rich, usually as camouflage of a ritual, carnival or other important festivals. Additionally, there are Venetian masks in Europe.

Ordinary gadgets
Some jewellery has practical value, like buttons, chatelaine, pins tying cloth, buckles, clips for hair, twins, brooches and pomanders. Because these ordinary objects have a sort of function, so they existed. The reason why this functionality is not taken seriously by ancient people is because the decorative function is much more important than functionality. (Figure.1.2)

2 Alba Cappellieri, Sentimental Jewellery, Marsilio Editori s.p.a., 2014, P27
Figure 1. Three silver Korean hairpins of the Koryo period (13th-14th century AD). The silver prongs have solid gilded heads, each with a small knob (missing on one of the pins) at the center of a ring of radiating incised lines and a scroll border. This is a very unusual form of pin, contrasting with the more usual, slender types. The scroll design can be paralleled in other types of metalwork and on other materials of this date.\(^3\)

Figure 2. A late Tang or Liao dynasty silver comb (10th century AD). The gilded upper section is worked with raised decoration enhanced with chasing, against a ring-punched background. This comb was intended to be worn in the hair. The decoration derives from Tang-dynasty bird and flower motifs.\(^4\)

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\(^3\) Hugh Tait, 7000 YEARS OF JEWELRY, Firefly Books, Updated edition, September 12, 2008
\(^4\) Hugh Tait, 7000 YEARS OF JEWELRY, Firefly Books, Updated edition, September 12, 2008
2.2 Functionality of accessories in modern society

With the development of science and technology, modern jewelry combines with functional products and wearable devices to expand the application range of jewelry. The combination of industrial products improves the aesthetic aspects and popularity of products, while increasing the functionality of jewelry. Combined with wearable devices, smart jewelry has less difference from the traditional jewelry. It is the product of wearable technology combined with fashion, and improving the appearance of the wearable devices. Moreover, it makes jewelry has more digital electronic functions, such as reminding messages and calling, GPS, marking locations and sending out distress signals and so on. It has unprecedentedly expanded the functionality of jewelry. The two types of functional jewelry will be elaborated and case analyzed.

2.3 Functional accessories in modern times

In the ancient age that was short of material culture, industrial products had the same source as the jewelry totally means of the same clan and origin. Later, the decoration of jewelry was stronger and stronger, which leads that jewelry is often considered useless, opulent and with no other function than to be decorative. Nowadays, in the rich material culture society, the single utility function of the product can no longer meet the needs of the people. The design of the product also changes unceasingly under the new demand, while the jewelry design can satisfy the esthetic need for users. Combined the ordinary industrial products with jewelry forms, functional items transformed into jewelry blurs the limit of industrial product and jewelry. While wearing functional jewels accessories, it is convenient to use some ordinary gadgets with fashionable outshape, which are both functional and aesthetic. Functional products performed as jewelry have satisfied the user’s psychological requirements on aesthetics.

Some gadgets like mini-notebooks, flash drives and dental floss, are usually forgotten to take with and easily to be lost. This problem bothers lots of users and takes inconvenience. Making the functional gadgets combining with jewelry, enduring jewelry functions and making functional gadgets aesthetic, which is a new trend for functional jewelry.

Dental floss dispenser ring

The dental floss dispenser designed by the author is used for the users who always eat out. Although some dental floss dispensers are designed really small and easy to take with, some users still always forget to take when they eat out. Or they put lots of gadgets in the bag and it is difficult to find out in the right time, which leads that they cannot clean teeth in time (Figure.3). The out-shape of dental floss dispenser ring keeps the real shape and color of the tooth, which can remind users to clean their teeth in time and pay more attention on oral hygiene and keep teeth healthy. The material is 3D printed resin and it looks like elegant ceramics. Putting the dental floss into the dispenser to ensure the hygiene of dental floss. Likewise, the dental floss is refillable and it can be changed a new one after using up.
2.4 TECH AS FASHION — — Fashionable wearable technology

At 1960s, the original intention of research and development of smart wearable devices is for the pilot with the display function of the headdress in the battle. The embryonic product of wearable devices can be traced backward to the 1970s, and the product became a hot spot in the fashion industry at that time. It could also be regarded as a revolution in wearable computing technology, and also the first time appeared as accessory. In 1997, the Massachusetts Institute of Technology, Carnegie Mellon University, Georgia Institute of Technology jointly organized the first international academic conference about smart wearables. After that conference, the wearable technology began to earn widespread attention in the academia, and then it showed the application potential gradually in the industry, medical care, military affairs, education, consumer goods, entertainment and other fields to demonstrate the application potential. In 2012, with appearance of Google glasses, wearables became a hot spot in an intelligence terminal industry, widely recognized by global markets. Nowadays, smart wearables’ market gradually becomes mature. Compared with smart bracelets made of plastic and silicone material as well as technical smart wearables for men, accessory-based smart wearables will be the next focus and hot spot. The application of smart accessories greatly expands the traditional function, such as real-time monitoring and analysis of information data from precise sensor hardware, virtual software, Big Data and other technologies, as well as perceived the bodies’ and the surrounding environment’s changes. Smart accessories have the advantages of small size, easy to wear, precise technology, real-time monitoring and other characteristics, provide users with a good human-computer interaction and product experience, and expand the accessories market with powerful functions.

Smart accessories are the wearable devices embedded in the clothing, jewelry, or the carry-on goods with the electronic communication equipment. It combines information collection, recording, storage, display, transmission, analysis, solution and other functions with the daily
wear, and becomes the smart wearable devices. Smart accessories not only has a certain decorative and aesthetic function, but also to meet people's living needs such as health, sports, shopping, entertainment and other functional requirements. Now there are so many smart accessories in the market, such as the smart glasses JINS MEME, TZUKURI, an unlosable glasses. As well as smart pearl accessories called Momento pearl, smart bracelet INTEL MICA and so on.

3. Analysis on the application prospect of smart accessories

3.1 Functional accessories solve common dilemmas

As the wearable’s market developments, new solutions for specific usability and functionality needs are emerging. Using jewels to treat some diseases is not modern inventions. As early as 1000 years ago, there were lots of people knowing the magical effect of jewels and use it in China and India. Emperor of Ancient Babylonian puts the gold cap as a crown with most often decorated with sapphire. Sapphire was recognized it had the treatment of fever, healing, cardiac and so on. The octagonal crown of Western Germany Otto I in AD 961, embedded with a piece of orange spar each side, which has a calming affect and life the state of tension. Another example is that, an actress from German admitted that she used crystal every time on the front of the lens. “With crystal reflecting my head, it makes me more concentrate,” said of the actress. In the New York Museum, it collected a funerary with crystal belly of the ancient Maya. The Germany psychologist Doctor said after studying the crystal belly, “The crystal belly is used as hypnosis when surgical treatment.” From this evidence we can find that European and Easterner have attached great importance to the magical healthy effect of jewels treatment. In modern times, Japanese scientists, according to the meridian theory of Chinese medicine, produced the magnetic therapy jewelry based on the theory that magnetic field can promote blood circulation.

Digital jewelry is a new branch of the wearable device that combines the wearable technology and fashion jewelry design while enhancing the beauty of the wearable device, which can attract female user groups. For the aesthetic need of customers, jewelry meets the health care wearables to solve some health problems. Currently on the market, healthcare digital jewelry products are mainly concentrated on the movement detection, reminding function and helping function. Its appearance is similar to the ordinary jewelry. With the increasing maturity of sensors, chips, communications, mobile Internet and other technologies, the awareness on health of national and demand for health services is improving. Wearable devices in the medical field have shown a huge application potential in such case. As of the end of 2013, 3 million patients obtained remote monitoring services by networked worldwide. ABI Research has predicted that the global healthcare wearable equipment shipments will reach 100 million units by 2020 with a developing prospect.
Sports fitness monitor, health care, entertainment and living convenience and environmental monitoring is the most normal functionality in smart accessories. And the products include smart watches, smart wristbands, smart glasses, smart headband, smart ring and so on.

3.2 Misfit case study for fashion smart accessories

Misfit a company established by former Apple CEO John Sculley and Sonny Vu in 2011 specializes in wearable technology that utilizes sensors and home automation products, owned by Fossil Group. Misfit’s wearable activity trackers are unique in design, and count sleep, calories, and basic steps that can be synced to a mobile app on a compatible smartphone. The first product Misfit Shine, which its first reviewers have called “fitness-tracking jewelry,” has gained great success after launching to the market in 2013. Later, it launched many kinds of fitness trackers like Misfit Ray, Misfit Shine 2, Misfit Flare, Misfit Flash and so on.

Dedication to quality and attracting female customers, in 2015, Misfit has launched Swarovski Shine Collection, which seamlessly blends jewelry design and technology. Joan Ng, Swarovski’s senior vice president of product marketing for the Asia-Pacific region, has explained that, according to their observation of wearable technology market, it would be an ideal time and a good chance for high-tech products to combine with some aesthetic elements, and transform them into fashion accessories.

The Swarovski Shine Collection, an upgraded version adorned with a violet Swarovski crystal that’s actually hiding a solar panel beneath that extends the wearable’s life from six months to whenever our sun burns out and you should never need to swap in a new battery. The Swarovski Shine Collection tracks and records all your daily activities including walking, running, swimming, sleeping, and more. After syncing the device with the Misfit app, the customers are able to view a daily summary including steps taken, distance traveled, calories burned, points earned and sleep pattern. It can be worn as a bracelet on the wrist, as a necklace and also attached to the clothes and shoes.

Misfit got good reviews from users who were attracted by stylish appearance and long life of using after charging. Other attractive points are the function of viewing time and waterproof, as well as it can be worn in everywhere around the body. Although some data are not accurate enough, customers also like monitoring their daily life as an accessory role.

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5 https://en.wikipedia.org/wiki/Misfit_(company)
6 Liz Gannes, "Misfit Wearables Raises $15.2M on Back of Shine, Even as Founder Dismisses Activity Trackers", AllThingsD, 4th December 2013
4. Future vision of functional accessories

4.1 More jewellery-like and more concentrate on the health sector

Technology is shaping a new anima mundi that by fusion crystallizes past, present and future. Jewelry is at a turning point and in its futures we may find unexpected pathways and unimaginable opportunities. In this context, the design guidelines for smart accessories will also change. The design criterion is also the focus of this paper.

Wearable devices are trying to conquer the market and to enter the users’ daily life. However, wearables show their limits when creating long-term engagement, which is crucial for helping the users to build healthy lifestyles that can accompany them during their lives. However, it will take time for mainstream adoption. In addition, as for future vision of functional accessories, as technology gets more advanced, it seems that the idea of functional fashion for the health sector is being taken more seriously. Nowadays, fast-paced life takes people lots of pressure that will be ten times than before. And jewelry is a kind of important accessories worn by modern people. This trend is the cooperation between fashion industry and sub-health topics. Helping young people alleviate the pressure and remind them to take care of their health with wearing fashionable jewelry is the duty of smart jewelry’s designer. Because being fashionable doesn’t mean you have to sacrifice function, and it is also a test for designers. On the other hand, wearables will become more jewelry-like and a kind of ornate and bridge the gap between fashion and function.

4.2 More applications with Internet of Things

Smart jewelry must not be a fashion replica of sporting bracelet, but covering all areas from rings, bracelets, pendants and other jewelry forms. The “smart era” has brought a colorful transformation to people’s life. Undeniably, smart jewelry is constantly improving their function, and the connection with smart devices such as mobile phones has gradually realized its connectivity with all aspects of human life. It is predictable that smart accessories will gradually realize the application of the Internet of things, such as the control of cars, air conditioners and smart TVs.

4.3 More daring ways to wear

The attachment method of wearable technology currently is still based on traditional jewelry forms, such as bracelet, ring, necklace, brooch and so on. In the near future, smart jewelry maybe will become false teeth, nails and other half embedded ways. Jewelry is not only some

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8 Alba Cappellieri, INTORNO AL FUTURO (AROUND THE FUTURE), Marsilio Editori s.p.a., 2014
9 Maurizio Caon, etc, Smart Garments and Accessories for Healthy Lifestyles, ISWC ’15 ADJUNCT, 2015 September 7-11
normal and limited forms. However, now it may be hard to accept and sounds absurd. But in the near future, when people go to the dentist, it's likely that the dentist will recommend dentures with a monitoring function to monitor the mouth and even the entire body.

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About the Authors:

Qingman Wu, lecturer from Beijing Institute of Fashion Technology in China. Participated in the 11th Asian Fiber Art Exhibition, Arts First Festival of Harvard University and other international exhibitions many times. Her research interests include fashion design and smart accessories design.
Abstract | According to a study conducted by ARS Toscana in 2014 the old people in Tuscany were 916.640 and there will be an increase of 36% in 2050. The “non-self-sufficiency” of elderly is a condition which entails their need of assistance. Often such a condition leads them to move from their home to the nursing home, radically changing their habits and everyday life. Over the past few years, robotics has represented a potential solution to improve the quality of life. This paper describes the methodology used for CloudIA research project, which concerns the development of an assistive robot to support fragile and non-self-sufficient people. An ad hoc questionnaire was developed to evaluate the acceptability. The questionnaire was addressed to 75 people, aged between 30 and 99 years, living in five nursing homes. The results allowed to target the design of the new robot.
1. Introduction

The aging of the population is a widely known phenomenon. Europe is facing unprecedented demographic changes due to the progressive aging of the population and low birth rates (WHO, 2002), producing a significant increase of the over-80s in the total European population, even if the highest variations they are registered in Mediterranean countries such as Italy and Spain (ARS Toscana, 2014).

According to the worldwide projections, by 2050 people over 65 will be more than the double compared to the children under five. Globally, by 2050, the number of people aged 65 and over will also exceed the number of teenagers and young people between the age of 15 and 24 (United Nations, 2019).

As a result, Europe is facing the challenge of offering high quality and affordable health care to all citizens. This challenge is very tough because of the increase of the medical care need for an aging society, the costs of treating chronic diseases together with the constant demand by citizens for ever better health care.

This trend, increasingly prevalent in Europe and in Italy, is significantly marked in the Tuscany region. In fact, according to a study conducted by ARS Toscana (ARS Toscana, 2014), by 2060 almost a third of Europeans will be over 65 and the demographic trends in Tuscany are even more pronounced. In 2014 the elderly in Tuscany were 916,640 and they will increase by 36% in 2050 and there will be an increase of 36% in 2050. A typical condition of the elderly in need of assistance is the "non-self-sufficiency", defined as a functional impairment in the basic activities of daily life (dressing, personal hygiene, movements at home or away from home and nutrition).

The aging process and its related dynamics results in significant changes in the market in terms of demand of products, services and environments for the quality of life, especially in the field of diagnostics and monitoring. Luckily, the emerging technologies have the potential to help the old people to maintain their independence. They can support the users in mobility both inside and outside home and in daily activities, promoting social relationships and improving the feeling of security and therefore delaying the physical and mental decline. This is confirmed both by the rapid development of smart technologies aimed at improving services in different sectors, and by their economic accessibility among the population.

One of these technologies is robotics. For example, the assistive robots represent a fast growing business, as well as one of the most attractive sectors in the field of medical technologies. They have the potential to maintain or restore the independence of older people in the near future (Ezer, Fisk, & Rogers, 2009; Fisk, Rogers, Charness, Czaja, & Sharit, 2009; Jayawardena et al., 2010).

Bearing all this in mind, this paper describes the methodology used during the Design phase foreseen by the CloudIA research project, financed by the Tuscany Region, which entails the
From the evaluation of acceptability to the design of an assistive robot for elderly

development of a robot to support fragile and non-self-sufficient people (elderly and disabled) in the nursing home (for the elderly and for the disabled) and at their own home. For that purpose, an ad hoc questionnaire was developed to evaluate the acceptability of four commercial robots: Pepper, Sophia, RP Vita and Paro. More specifically, the following factors were assessed: appearance, humanity, facial expressions and adaptability. The results that emerged enabled the authors of this article to direct the design of the new robot.

The questionnaire was administered to 75 users, aged between 30 and 99, hosted in the 5 cooperatives involved in the research program.

2. Approach to acceptability evaluation

Over the past few years, robotics has become a potential solution to improve the quality of life of the users and the services provided to them: robotics can improve mobility, communication possibilities, promoting social inclusion and increasing the sense of security, e.g. through systems for monitoring vital signs and daily life activities (Jayawardena et al., 2010).

The scientific literature (Forlizzi, DiSalvo, & Gemperle, 2004; Goodrich & Schultz, 2007; Information Resources Management Association, 2017) provides many examples of robots developed to meet the needs of the users: health monitoring, drug assumption support, physical assistance and mediation between users and assistive technologies. Assistive robots can be classified according to the need they satisfy, including:

- robots for socialization;
- information robots;
- security robots;
- health robots;
- leisure robots;
- robots for physical support.

However, these technologies are not used yet, due to factors such as stigma, (non) adaptability or social influences (Heerink, Krose, Evers, & Wielinga, 2009).

Robotics appear as groundbreaking but, in the coming years, it will have to find a place among human beings and humans, in turn, will have to accept this technology.

To avoid a human-robot incompatibility, it will be important to ensure the acceptability and the adoption of robots by people. On this basis, the researches in the Human-Robot Interaction (HRI) field aims at understanding, designing and evaluating robotic systems for use by or with humans (Goodrich & Schultz, 2007). The HRI therefore focuses on the two
dimensions of interaction: the physical one, which is often referred to as teleoperation or supervisory control and the social one, referred to social, emotional and cognitive aspects.

One of the key elements of the HRI is acceptability, together with safety and usability requirements (Salvini, Laschi & Dario, 2010).

In robotics, the concept of acceptability has received considerable attention, especially in the field of biomedical devices, such as surgical robots and robotic prosthesis, but it is gaining relevance also in the field of assistive devices and companion or domestic robots (Dario, Guglielmelli, Genovese, & Toro, 1996; Salvini, Laschi & Dario, 2010; Welch, Lahiri, Warren & Sarkar, 2010)

Acceptability is usually described as the “demonstrable willingness within a user group to employ information technology for the task it is designed to support”. The goal of acceptability is to measure and identify key determinants of user acceptance or resistance (Dillon, 2001).

The term “acceptability” is “user-centered”: it is exclusively based on the study of the relationship between a product and its user (Salvini, Laschi & Dario, 2010).

Robotics therefore opens new challenges for the discipline of Design and consequently for designers. The contemporary society needs products that meet people’s needs through a human-centered design (HCD).

This brings the need to develop evaluation methodologies. In particular, in the field of robotics and screen agents several methods have been used, varying from applying heuristics or other usability type tests and classifying tests to measuring physical responses (Heerink, Krose, Evers & Wielinga, 2009).

The approach and the methods of Human-Centered Design are one of the possible strategies for innovation in the European production system and also for the small and medium-sized enterprise system (EU Commission, 2013).

Designing the acceptability (Design for acceptability) consists in applying principles and methods during the early stages of robot design in order to minimize the risk of resistance or rejection by users. According to some authors, designing acceptability means understanding the factors that can influence the adoption of technologies (Dillon, 2001) and assessing the HRI through five main methods: interviews, self-assessments, behavioral measures, psychophysiology measures and metrics of task performance (Bethel & Murphy, 2010).

This paper shows the methodology used for the design of a new robot. The presented methodology provided for the active involvement of end users (elderly and disabled), during the first Discover phase (as proposed by the Design Council’s Double Diamond). Users completed a questionnaire for the evaluation of acceptability: the questionnaire was focused on those morphological, both general and specific aspects, able to give rise to users’
likeability and influence their attitude toward the robot. The main focus of the questionnaire method was to define the guidelines for the development and design of the new robot.

Given the nature of the end users and their location on the whole regional territory, the questionnaire was found to be the most effective method among those present in the literature, because it allowed to receive quantitative data in a short time (Stanton, Young, & Harvey, 2014). Data were subsequently interpreted and used during the design phase of the new robot.

After a review of the scientific literature relating to the acceptability of robots, the questionnaire was developed, with a special focus on Mori’s Uncanny Valley (Mori, 1970; Mori et al., 2012). According to Mori, there is a non-linear relationship between the likeability or familiarity and the humanoid aspect of a robot. The appearance of a robot, when it is too similar to a human being, could annoy and generate in the observer disturbing feelings such as anxiety or negative attitudes (Mori, 1970; Mori, MacDorman, & Kageki, 2012).

According to the study conducted by Dario et al., the appearance of an assistive robot should not necessarily be anthropomorphic. Consequently, the best design solution should be a balanced mix between the domestic device appearance and the machine appearance (Dario, Guglielmelli, & Laschi, 2001).

On the contrary, Breazeal claims that when designing a robot, it is essential to consider that humans, as an extremely social species, uses his socio-emotional intelligence to understand the behaviour of more complex entities, like people or other living things. Human beings interact with other non-living elements with sufficient complexity, applying social models to explain, understand and also predict their behaviours. For example, people are known to anthropomorphise all sorts of technology (e.g. cars, computers, etc.) (Breazeal, 2003).

The same author also argues that people generally apply a social model when they observe and interact with autonomous robots. Autonomous robots make decisions and perform actions independently to perform their tasks. This makes them, for human beings, similar to a creature with which they can communicate, cooperate and learn from: for this reason, it is almost impossible for anyone to not anthropomorphise them (that is, to attribute human or animal qualities to them).

As claimed by Breazeal, aesthetics is fundamental in a robot:

“when designing robots that interact socially with people, the aesthetics of the robot should be carefully considered. The robot’s physical appearance, its manner of movement, and its manner of expression convey personality traits to the person who interacts with it. This fundamentally influences the manner in which people engage with the robot” (Breazeal, 2005).
2.1 The questionnaire

As stated by some scientific evidences (Johnson, Slaughter, & Carey, 1998; Scheeff, Pinto, Rahardja, Snibbe, & Tow, 2002; Minato, Shimada, Ishiguro, & Itakura, 2004; Breazel, 2005), the morphological aspect of the robot can influence its interaction with the human beings. This is more evident in relation to specific groups of users such as the elderly. Therefore, in the period from May to October 2019, an online questionnaire was sent to the 5 cooperatives partner of the CloudIA research program.

The specific objective of the questionnaire was to understand how the end users perceive the four selected commercial robots, and which aesthetic features they accept and find more likeable and acceptable. The four commercial robots were chosen after a careful review of the scientific literature as well as for their functionality and services provided.

As a result, the following robots were selected (see Figure 1):

- Pepper (Android), produced by the Softbank Robotics company. The robot is able to talk, understand, move independently, and react to emotions;
- Sophia (Humanoid), produced by Hanson Robotics. It is a platform created for advanced robotics, for AI research and for exploring the Human-Robot Interaction;
- RP Vita (Automaton), produced by AB Medica. The robot provides the remote presence service within hospital and care-intensive environments;
- Paro (Zoomorphic), produced by Paro Robots. The robot was designed to provide therapeutic assistance to various kinds of patients. It can be used both in the hospital and at home.
From the evaluation of acceptability to the design of an assistive robot for elderly

Figure 1. The four selected robots for the questionnaire.

The questionnaire was submitted to two categories of users (elderly and disabled), aged between 30 and 99, all hosted in the cooperatives partner of the research. 75 users of both genders participated in the questionnaire. The questionnaire consists in 4 yes-or-no questions and 1 open-ended question:

1. is this robot beautiful? Y/N
2. is this robot likeable? Y/N
3. would you stay alone with it? Y/N
4. would you hug it? Y/N
5. is there anything in particular that you like?

3. Results

The data collected from the acceptability questionnaire are shown below.
17 males and 58 females replied to the questionnaire. 12 of them were under 65 (<65) while the other 63 were over 65 (>65). Table 1 shows in detail the age of the users who took part in the survey (see Table 1).

As for the first question "is this robot beautiful?", most of the participants showed pleasantness towards the robots Pepper, Sophia and Paro. While for the RP Vita robot only 49% said that the robot is beautiful (see figure 2).

As for the question "is this robot likeable?", the data relating to the 4 robots are very similar (see figure 2).

Different results emerged from the question "Would you stay alone with it?". As shown in figure 2/question 3, the 49% of the interviewees would stay alone with the Pepper robot. While the 51% would stay alone with the Sophia robot. As for the RP Vita robot, only the 41% would stay alone with the robot and the 60% of the interviewees would stay alone with the Paro robot.

The results from the question "would you hug it?" are very different. The 65% of users would not hug the Pepper robot. The 56% would not hug the Sophia robot, and the 80% of interviewees would not hug the RP Vita robot. The 56% of interviewees said they wanted to hug the Paro robot (see figure 2).

<table>
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Table 1. The age of the users who took part in the survey.

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</table>

Figure 2. The data emerged from the questionnaire.
The results that emerged from the question "is there anything in particular that you like?" are very interesting.

As shown in figure 3, although many of the interviewees stated that there is nothing particularly beautiful in these robots, the data suggest a high degree of pleasantness towards the following characteristics of the selected robots:

- face;
- eyes;
- mouth;
- hands;
- arms.

In conclusion, the results show a strong tendency to appreciate soft and smooth shapes, with non-humanoid features.

Furthermore, the display is not considered as an annoying feature of the analysed robots.

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**Figure 3. The results from the question: “is there anything in particular that do you like?”**
4.1 The new robot: CloudIA

Before proceeding to the design of the new robot (sketch, 2d and 3d drawings and renders), simultaneously with the submission of the questionnaire, together with the cooperatives involved in the research program, the desiderata were defined: they were useful for defining the new robot features in relation to the real needs and expectations both of the end users and of the health care workers who provide daily service in the nursing home for the users and also at home.

The desiderata allowed to design a new robot for assistance, socialization, active support for hydration and for the assessment of users' cognitive and/or physical abilities, to be used both in nursing home and at home (Pistolesi & Becchimanzi, 2019).

After the definition of the design brief, the design and development of the robot was conducted on the basis of the user analysis. Specifically, the development of the robot was carried out on the basis of the results that emerged from the desiderata and the acceptability questionnaire. Moreover, the new robot was designed also in relation to the robotic platform designed and assembled by the Institute of BioRobotics of the Scuola Superiore Sant'Anna in Pisa, a research partner together with the authors of the CloudIA research program (see figure 4).

Although the robotic platform has constrained the shape of the new robot, its final shape is smooth and balanced, without protruding elements or edges. The chassis of the robot is made by three elements: a right part, a left part and a compact hinged door with magnetic closing. The basis is larger than the top so as to ensure the stability of the entire robot. The chassis topcoat are smooth and soft. In order to satisfy sustainable aspects, the entire body of the robot is made by plastic urban wasted 3d printed.

Furthermore, it was necessary to design a mobile arm to orient and support the tablet. It is fixed to the highest part of the robot chassis in order to allow the user to arrange and interact with the display. This feature provides a greater humanization of the robotic platform.

The height of the new robot, and consequently the customizable position of the tablet, allows all users to interact with the tablet without excessive effort.

The tablet is useful to carry out the following activities:

- hydration support through an alert;
- support to drugs intake through an alert;
- socialization activities in common areas;
- emotional/cognitive status monitoring through the submission of the Mini-Mental State test (Folstein, Folstein, & McHugh, 1975), currently used by the 5 cooperatives;
- cognitive stimulation.
These activities will be tested within the 5 cooperatives involved in the research program.

*Figure 4. The robotic platform assembled by SSSA.*

*Figure 5. The new robot.*
From the evaluation of acceptability to the design of an assistive robot for elderly

Figure 6. The new robot.

5. Conclusion

This paper presents an experimental methodology, aimed at applying the Human-Centred approach to the design of assistive robotic technologies. In fact, as stated by Forlizzi et al. (Forlizzi, DiSalvo, & Gemperle, 2004), many of the products analysed by the scientific literature on assistive robotics, have been designed with little consideration of the social, aesthetic and emotional relationships that the users will establish with the product.

The HCD (Human-Centred Design) approach, applied by the authors of this article, focuses on the analysis of users’ needs, aspirations and expectations declared and/or tacit, so that they provide the basis for the design of the new robot.

The experimentation and design development presented in this paper are based not only on functionality and efficiency but also include elements such as attractiveness, likeability and the absence of stigma and non-reluctance towards technology.

The research methodology was aimed at obtaining feedback on the various personal aspects that contribute to generating the complex human-product interaction. Although this is influenced by extremely subjective factors and the personal experience of each individual user, it can be designed according to universally shared patterns and features.

The collected data contributed to the development of an accurate knowledge of the profiles of pilot users who will subsequently interact with the robot.
In addition, although the Design is often associated only with the aesthetics of products, its application is actually much wider. The Human-Centred approach therefore becomes a fundamental requirement in order to create a truly suitable, useful and acceptable product.

In conclusion, the next step of the research program concerns the definition of a new experimental protocol aimed at evaluating the overall experience of Human-Robot Interaction, through the analysis of the emotional quality of the interaction, such as acceptance, safety, intentions, perceived likeability. The experimentation will be conducted with pilot users both at home and in the nursing home for the users.

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Future heritage and heritage futures. 
A design perspective on the activation of Digital cultural heritage stored in archives.

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Abstract | This contribution aims to investigate what role archives of digital cultural heritage can have for the creative industries, and to understand the inverse relationship: how design culture can foster the activation of digital archives aggregators in order to stimulate the production processes of new cultural expressions. This research was conducted with the aid of a specific case study: the Europeana platform, the multi-thematic aggregator of European Cultural Heritage. If Heritage is to be considered as a process and result of a relationship with the past and attributing it social and cultural meanings in the present; and if the objects contained in the digital archives are Heritage themselves, considerable research efforts should be made to develop project proposals relating to the use of those objects.

KEYWORDS | DIGITAL HERITAGE, ARCHIVES, CULTURAL PRODUCTION, CULTURAL PARTICIPATION, DESIGN FOR DIGITAL CULTURAL HERITAGE
1. Cultural process of heritage

In its current meaning, Cultural Heritage is identifiable as a broad term whose value is mainly of use, and it is rooted in the ability it can have to generate new culture. GLAMs (Galleries, Libraries, Archives and Museums) have been overwhelmed by a profound change already in the way of understanding heritage, which has shifted from protection of cultural assets by their conservation to a vision of protection intended for use. With the Faro Convention (European Commission, 2005), attention turns from the object -cultural heritage- to the subject - citizens and communities - and participation becomes the key to increasing the value of heritage. This value is mainly expressed in the use and in the ability that society has to introduce it into the processes of creating new culture.

In this transition, Heritage protection is needed to be also meant as attention to the process that allows its creation (Bortolotto, 2007). Thus, consumption and production of culture are part of the same process that is historically fluid and can be identified in a Continuum. Cultural heritage, therefore, becomes an "umbrella term" which incorporates material objects, rites, traditions and know-how, closely connected to each other. Tangible and intangible cultural heritage are interdependent; they no longer represent something circumscribed and concluded but are part of a fluid process.

From an idea of heritage firmly rooted in the monument, in the document, we are witnessing a shift towards a process-oriented approach. "There can be no folklore without the folk, no traditional heritage without living participants" (McCann et al., 2001).

This type of approach considers heritage deeply rooted in the contexts that generate it, according to a dynamic vision of a culture that continuously produces its expressions. In this perspective, heritage is not only symbolic but is alive and needs the communities of heirs to appropriate and use it.

Moreover, digital technologies have had a significant impact on GLAMs, prompting them to rethink their role and functions completely. The grouping of cultural institutions under an acronym, in fact, already suggests almost imperceptible differences and blurred boundaries. This contribution aims to investigate what role digital archives can have for the creative industries, and to understand the inverse relationship: how design culture can foster the activation of digital archives aggregators in order to stimulate the production processes of new cultural expressions. This research was conducted with the aid of a specific case study: the Europeana platform, the multi-thematic aggregator of European cultural heritage.

Hence, if heritage is the process and the result of a relation with the past and attributing it social and cultural meanings in the present (Smith 2006; Harrison 2013); and if objects contained in the digital archives are heritage themselves, considerable research efforts should be made to develop project proposals relating to the use of those objects.
2. Archives of digital cultural heritage

Digitization of the historical-artistic heritage concerning safeguarding, activation, and enhancement today has a widespread role, and it is possible to state that in its emergence, it has assumed the features of a sort of invasion that is anything but gradual. The progressive digitization has dramatically enriched the archives and, together with essential initiatives for Open Access, has made a large amount of digitized cultural objects freely available online. However, it happens that digital archives do not find sufficient response in public in terms of consultation and even less of use; moreover, in many cases, the alleged recipients of the service do not even know its existence.

Technological evolution has affected every aspect of our lives, including the dynamics of heritage. However, the irruption of new technologies does not represent a wild colonization of heritage territories (Burdick, A., Drucker, J., Lunenfeld, P., Presner, T., & Schnapp, J. 2012), but is a result of changes in cultural paradigms that have led to making also digital reproductions rightfully part of heritage (UNESCO, 2003).

Therefore, digital archives need to be placed in that continuous process of creation of which heritage becomes a vehicle and interpreter. Digitized and accessible online cultural objects potentially represent an "open-ended knowledge system" (Sennett, 2008), composed of forms, processes and cultural contents to be used as tools to build a "collective memory" (Halbwachs, 1992) (as traditionally happens), and above all as resources for the production of new cultural contents.

GLAMs have progressively digitized their collections, and many institutions have chosen to make them available online, not as a surrogate for the physical museum, but as a digital archive that can be consulted anywhere. Then, cultural institutions have begun to wonder whether the internet could become a tool for disseminating evidence of preserved knowledge. In this new scenario, some pioneering institutions join the Open Access and Creative Commons movements and "free" their collections by renouncing reproduction rights. Thus, it is possible to perceive a matured awareness of an archive heritage that need to circulate, be used and re-used, all actions that are finally possible thanks to the new digital dimension.

The archive, therefore, assumes an active role in the present and is part of every cultural institution, extending its meaning: no longer an institution dedicated exclusively to the conservation and cataloguing of obsolete documentary material, out of the everyday use, but potentially dedicated to the activation. Thus, it is possible to observe a conceptual shift also in the field of archives, an emerging role in the process of building memory.

2.1 The archival turn

Heritage in digital format leads the archives towards a substantial change in functions and purpose, the “archival turn” (Bearman, 1991, 1994, 1999; Cook, 1994; Duranti, 1997, 2001): archives are no more considered as places of passive storage, on the contrary they had become containers of information ready to be used.
Terry Cook argued that digitization required a great change in the role of the archivist: as a creator and custodian of “physical things”, now is called to make sense of electronic information in relation their context, structure and content (Cook, 1994).

The scenario is of a lively, animated archive (Schnapp, 2013) and digitization fosters two types of transformations: the first, quantitative, concerns the abatement of the space-time constraints that allow access to information in a short time and remotely. The second one is purely cultural, since being able to consult the archives digitally modifies "the forms of knowledge production" (Vitali, 2011). The growth of digital archives, therefore, affects the way in which it is possible to approach the past, explore it, know it, process it and transmit it. The “archival turn” lead to numerous initiatives aimed at access to DCH material, giving life to "invented archives": the aggregator that collects material belonging to different institutions under a single website, as Europeana.

Moreover, thanks to the Open Access movement, a conspicuous number of DCH material is now available with Creative Commons 0 (CC0) licenses, or Public Domain: freely reusable for any purpose, ready to be reworked and transformed, representing an important unexpressed resource for project cultures.

Recognizing the process also in archives brings changes in the concept of the archive itself. If (traditionally) the term presupposes a closed inheritance, a sort of "memory delivered", the documents are no longer preserved, but "buried" in an archive. However, according to these reflections, the archive can no longer be understood as a warehouse but as a factory that allows, in its continuum, to (re) write history, (re) write the present and the meaning of the present before it appears (Barnet, 2001): it is a project tool.

3. The Europeana case study

Europeana is an aggregator of digital archives of European heritage, and in this research, is taken as the main case study. It was born in 2008 and declares to address scholars, GLAMs, and cultural and creative industries (Europeana, 2015).

The case study analysis consists in a first phase of desk research, and a semi-structured interview submitted to internal individuals and experts from Europeana. Then, to verify the starting hypotheses, a questionnaire was developed to be disseminated to designers and creatives in order to understand how their creative process works and what tools they use. Subsequently, the current model was analyzed according to how Europeana relates to its users, taking into consideration the semantic evolutions of the catalogues (Bianchini 2015), which aim to improve the archives, but are rarely strengthened by studies on the satisfaction of end-users (Feliciati, 2016).

In more of a decade, Europeana made considerable efforts to collect a mass of digital material that is currently almost impressive (about 58 million objects from all over Europe). Moreover, together with the crucial Open Access and Open Culture initiatives, Europeana allowed much of this material to be available with Creative Commons 0 (CC0), or Public Domain licenses, representing an essential resource for cultural and creative industries.
Among the main successes of Europeana is data standardization. The portal offers standardized procedures and APIs (Application programming interfaces) in order to offer GLAMs the tools to continue digitizing, and to introduce qualitatively better data into Europeana. Free access to standardized APIs also allows professionals to develop digital products and services that directly access Europeana content.

Current practices are still strictly focused on the quantity of digitized content and quality linked exclusively to the attributes of the information entities and mostly to their system of connections (metadata). At the same time, less attention is paid to the purpose and method of access and of use (re-use) of the contents.

The Europeana platform proves to be a tool with potentially extended opportunities, but due to the more considerable attention paid to the quantitative aspect of the collection of an increasing number of records, compared to the dissemination, knowledge and encouragement of initiatives aimed at re-use, still presents significant conceptual problems. From the analysis emerged that the development of Europeana was rooted in the idea that by building the infrastructure, the platform would help create opportunities and these, in turn, would generate value (Fallon, 2018). However, in recent times the platform seems to have noticed that it has achieved "too much": too much material, too generic, too many records to improve, too large the target audience, etc.

Despite a large amount of digital material collected, the development of standardization systems for the collection and management of data, Europeana still cannot reach the people it wants and above all not in the way it wants. In this regard, it is believed that the IT structure should be considered as a means, not as the end: the end is the experiences, knowledge and combinatory actions that the aggregator can generate.

The independent assessment on Europeana (Enumerate, 2018), shows that the project still has significant criticalities that are not only of a technical-technological nature. The most critical aspect lies in the knowledge and use of the portal by the primary recipients and stakeholders. The report shows that more than 50% of respondents do not consider themselves satisfied with the results of their Europeana research, particularly regarding the relevance and accuracy of the results. Moreover, more than 50% of the respondents admit they were visiting the platform for the first time, or they visit it once in a while. There is, therefore, an obvious problem of engagement and participation.

In the face of the analysis carried out, a lack of focus is therefore identified in the progressive change of objectives which has not led to an evolution of the strategies, but rather from time to time to adaptation. Indeed, since it is an immense project and the outcome of financing programs, it is possible to understand how difficult it is to make substantial changes in such complex contexts.

In the case of creatives, the situation is even more critical. From the results of the questionnaire, it emerges that among 100 designers no one had ever heard of Europeana and, of course, no one had never used it before.

Technical problems related to the data structure are partly solved and certainly far from the competences identifiable in design research. Efforts concerning the participation of the users and ways to use and reuse the material in order put it into processes of creating new culture
seems to grow in importance, and that is a matter of design research.
In the wake of Jeffrey Shnapp’s reflections, what happens when we move from a selected collection to the immense? from tens or hundreds of cultural objects to hundreds of thousands and tens of millions? "How do we navigate, describe, analyse", but above all interpret cultural heritage "with, on and through these enormous aggregates?" (Shnapp, 2013). It is precisely here, in the relationship and in the mediation, that design can and should take action.

4. Design and digital archives of cultural heritage

Cultural heritage and archives have experienced a profound conceptual transformation that has led both domains to be no longer static and custodian, but processes dynamic and continuously evolving. Both the heritage and archive processes in the digital context tighten a relationship so close as to sometimes overlap (Gibbons, 2014): layers and contexts, assumptions and relationships make the cultural heritage and the archive highly integrated. However, when it comes to the relationship with information technology, the traditional training of the archivist still has some gaps and highlights the need for deep interdisciplinary collaborations (Hölling, 2015). Often, digital archives fail to make themselves explicit in this new role that emerges since it is not sufficient to translate the physical object on a screen to allow it to become something new. The exploration of how and where in this translation values and meanings can be added and not subtracted grows in importance.

In other words, it is a question of knowledge design (Shnapp, 2013) but also of strategic design. The archive today has the potential to allow the creation of new visions, to become an entity no longer static but dynamic and directed towards the future.

New interactions emerge, enter the archive and transform it. On the basis of these observations, the research starts from the hypothesis that through a project action on the archive, which is not reduced exclusively to a design of the interfaces but involves a project of a strategic type, of the meaning, of the information and of the relationship between the archive and the designers, these aggregators can truly emancipate themselves and become an instrument of design and creation of the heritage of the future. The action of design can generate different impacts by improving visibility and engagement but also drastically changing the role that the archive plays today and its meaning by extending it to a use that is not exclusively specialized.

Recognizing the relational need of heritage, the need it has to be in relationship with people to be interpreted and manifest its value, every action of design in this direction is a "relational project of cultural heritage" (Lupo, 2007). In this case, the action of design can convey the relationships within and around the heritage, triggering construction and generative processes of new heritage by moving away from mere enhancement to achieve activation.

This happens for the development of the technologies of which design has always become a vehicle. We are in a time when design and cultural heritage do not meet only within
museums, therefore the unexplored area that this research intends to occupy concerns precisely this space of relationship outside museums. The focus is on the relationship that design and cultural heritage can have thanks to digital archives, or in the context of digital archives.

The field of application of design to the territories of the heritage today concerns more the relational and visual aspect than the material one, and digital technologies propose the exploration of new interpretative models also in the context of archives. Hence, it is possible to argue that design can play an essential role in this translation, in this threefold relationship that over time it has built between technology, cultural heritage and design.

What emerges is a vaguely paradoxical picture in which the action of design makes its way into the development of strategies or proposals aimed at bringing people closer to heritage while the product of design, being part of the cultural and creative industries, is itself recognized as heritage. It follows that design is both an active actor and a result of this process of continuous creation which identifies itself with cultural heritage; design helps to produce the cultural heritage of the future by interpreting the present and the past and at the same time designs the relationships that can allow this construction.

Conclusions

This contribution adopts an approach that aims to remove disciplinary barriers between the tangible, intangible and digital dimensions of heritage. It wants to stimulate to look at creation and conservation as aspects of a single cycle, of a single process. Taking care of the digital cultural heritage also means promoting its regeneration, supporting contemporary creativity.

Continuous use and active participation in heritage dynamics can trigger a whole series of impacts and externalities, both positive and negative (Sacco, 2018). Heritage can identify as a set of social and cultural processes that are mutually interconnected, interacting with each other and with the external environment, which reacts and evolves as a whole, in short, as a system.

Material, immaterial or digital, it is heritage in its past being that is handed over to the future to be an active part of it and to help build it. Design has the ability to connect, to act as a catalyst to lead to the desired change that sees the material contained in the aggregator genuinely become part of the heritage process of creation and construction.

To do this, design needs to work with its skills and competences in interdisciplinary projects that deal with the organization and activation of archives. What therefore emerges is that design can begin to deal with these archival contexts, first of all by working on meaning.

In conclusion, design can begin to deal with the heritage creation dynamics that can be triggered thanks to the archives by offering its expertise, at several levels and in several stages.

"Creativity does not happen inside people's heads, but in the interaction between a person's thoughts and a socio-cultural context. It is a systemic rather than an individual phenomenon
"(KEA, 2006)

Even the art world, for example, has always turned to the past to produce the new: Manet could not have painted the Olympia without having Titian's Danae as a reference, Andy Warhol uses objects symbol of mass culture such as the Brillo boxes, and Jeff Koons has repeatedly reworked the sculptural works of the classical world in his works. Copying, pasting, inspiring, quoting, reproducing and scrambling are terms that have always belonged to the vocabulary of the creative industries. It is precisely in the very nature of the heritage that the ability to implement new realities through contingent processes of assembly and reassembly of bodies, technologies, materials, values, temporality and meanings (Harrison, 2016).

The digital material contained in the archives represents an essential resource for creative industries such as design or fashion design as well as for contemporary artists. Those are among the areas that can benefit most from Digital Cultural Heritage to introduce it into new processes of creation of what will be the culture of the future.

This study is rooted in the awareness that DCH materials acquire value only if they are understood, interpreted and used: they need to be involved in the continuous process of creation and construction thanks to a design action. Hence, relationship and contamination that has always existed between the culture of the past and contemporary creativity, seems to be essential to explore the 'future heritages' and 'heritage futures'.

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Going beyond the problem of privacy: individual and social impacts of the use of personal information in connected services.

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Abstract | We are seeing an incremental spreading of devices able to collect and use personal data. Many types of services such as personalized assistance, healthcare solutions and smart cities rely on personal data for the improvement of the service. The management of personal data allows services provider to add value within the system and design practice needs to understand and consider the impacts that personal information can have on the individual in terms of changes on personal awareness, on actions the individuals perform, on relationships with other individuals, and on individual agency in the society. Personal data is now a matter of design for product and service in order to push forward the technology advancement avoiding serious consequences. We need to design services in a conscious way considering possible issues related to the use and sharing of personal information while exploiting the value that this information can have in the services.

KEYWORDS | PERSONAL INFORMATION, INDIVIDUAL IMPACTS, SOCIAL IMPACTS, PERSONALIZED SERVICES, SERVICE DESIGN
1. Introduction: technologies and the use of personal data

We live in a world where the incremental spreading of products and devices that embed sensors and logging mechanisms allow to detect, collect, store and manage personal information (Greengard, 2015). Companies and service providers take advantage of this ability to create personalized experiences to the final users as well as gather knowledge from the information collected. The current trend of hyper personalization of services that aim to provide an extremely tailored experiences for users, strongly needs data that describe the behavior, the preferences and the habit of people as a knowledge base and as a continuous feeding for the adaptation of the services’ reactions and proaction. Despite the usefulness of personal data analysis for services, the persistent and ubiquitous collection of these data raises several concerns, one of this is that users cannot actually avoid providing their data for two main reason: first, they are not really aware of some automatic tracking; second, service providers often deny accesses to services if the consent of sharing data is denied by the user.

Figure 1. Revised DIKW Model.

In Figure 1 I represent the Ackoff’s DIKW canonic model (Ackoff, 1989) revised so to generally frame it within the process of creation of wisdom from personal data in services. Starting from the physical world in which all the presences and actions take place, devices record the properties of individuals and related data. Devices can be seen as objects as well as environments that embed sensors that record the data in the systems. This recording of properties represents the ‘what is’ and ‘what happens’, creating the reference of the physical phenomenon on digital supports. To create the information, the technological solution (algorithms) processes data through elaboration, data crossing and/or aggregation. Technological solutions can then give back the processed information to the users as well as analyze it to create knowledge and understanding of phenomena. When the analysis of information is made by users from the visualization of information, personal skills in interpretation is key: the person must have the capability to understand the provided information thanks to the application of background contextual knowledge that supports a proper analysis. Being it performed by interrogation systems or by the user through the
interpretation of information visualization, the analysis of information needs the application of reference knowledge that allow to properly interpret the information. The knowledge extracted from the analysis is given back to the users in the form of insights, suggestions through the proactivity of the service. The generation of wisdom relies only on the human abilities and evaluation according to the individual’s ethics, values, culture, political and social vision, and personality traits.

2. Using personal data to add value within the service

The single person generates data that can be collected from conscious and active providing made by people (e.g. sharing of content, activities and presence through social networks) as well as passively gathered from user’s actions in both digital and physical worlds. People are surrounded by technologies (such as cameras, scanners and many other different sensors) that are capable to gather information about them. People carry around powerful devices that are able to communicate with the surrounding systems. In everyday life, we move from A to B in different ways such as riding a bike, driving a car, or catching a bus and paying the ticket for the ride. We walk on streets looking for specific places with the help of digital maps that constantly track our position. Users rely on systems that provide them useful information, insights and alerts about themselves, about their everyday performances, about what and who surrounds them. Private and public companies, governments, and other public and private actors have the power to collect and use data to enable service’s functions, to personalize the user experience, to create legitimacy through identity verification, to provide access and authentication, to create new services and to improve already existing services (Joinson et al., 2010).

Modern services rely on self-tracking devices (Neff & Nafus, 2016), personal logging and automatic detection of personal data from ambient intelligence (Gunnarsdóttir & Arribas-Ayllon, 2015) to integrate the knowledge about the users and to know them in detail. Current available solutions and ongoing projects in many fields imply the use of personal data for several purposes. While personal devices tailor fitness and wellness experience providing hyper-personalized feedback to the user to trigger actions for goal achievement (Neff & Nafus, 2016), they can be also a source of knowledge about health status that healthcare providers can use for services to engage and support patients through interactions with personal information. This also enable the shifting of the healthcare paradigm from cure to self-care and prevention of illnesses (Lupton, 2013). Modern home appliances not only react according to user’s control as they ever did, they allow remote control, use behavior analysis, and collect users’ preferences to enable the proactivity of the services. The systems provide insights and automatically perform and manage tasks such as good purchase and automatic heating. Home automation systems move to a comprehensive house management that integrates all these tasks to reduce cognitive efforts and number of interactions (Pillan & Colombo, 2017).
Moreover, service providers not only take advantage from the data analysis to provide better and more tailored services, they can also imply the knowledge derived from such data to promptly adapt the company strategies to fluid markets that constantly change day by day, as well as provide knowledge to other stakeholders involved such as governments, research and other actors that can make profit or have non-monetary advantages. The sharing of patients’ data can make a difference in the advancement of medical research (Weitzman et al., 2010) as well as cities and governments take advantage of citizen’s data to improve and better manage public and private services (Goodchild, 2007) (Mitchell, 2010) (Ratti, 2010). The creation of services that rely on the use of personal information is a complex chain of value creation that starts from the human element. The value that the of personal data add to the service can be of two types: awareness and function.

2.1 Awareness as service value: enhance self-knowledge and support behaviour change

The practice of tracking personal data is able to increase self-knowledge through the analysis of personal traces (tracked data) and the derived information (Ferraris, 2009) (Buckland, 2017). Reading visualization of personal information, the users increase their knowledge about activities performed, about personal preferences and trends, and about body behaviours. Self-tracking is also able to promote behaviour change in a goal-oriented approach. Figure 2 shows how feedback-loop leads to behaviour change using self-tracking as a support. (Lupton, 2016) (Young, 2013). The feedback-loop derived from data tracking is broadly used by services and systems as a way to promote and support behaviour change in several fields of applications. It is often a core part in the switch of paradigm in healthcare from cure to prevention and self-care where the patient becomes a participant actively involved in self-care (Marr, 2015) (Lupton, 2013) (Lupton, 2017).
Despite the creation of feedback-loop can involve uniquely personal interactions with the user’s own information, some service offer the opportunity to reinforce behavior change mechanism through the comparison and sharing of personal data with other people improving personal knowledge of the individual and among the community, and engaging in a community goal-oriented approach (Lupton, 2016) (Lupton, 2013).

2.2 Function as a value for the service: increase the proactivity, and improve the experience

As mentioned before, the knowledge derived from personal information, can be used by interactive artifacts to increase the proactivity of services and to improve the functions through wearable prosthetics, beacons (Purpura et al., 2011) and residential objects (objects that belong to living places and aim to enhance the relationship between individuals and their networks, and between human body and the environment), as well as to enhance the potential of places through physical objects/devices in public spaces. Services that rely on users’ personal information to provide personalized insights, tasks and goal, have a higher level of proactivity toward the individuals. The digital solution becomes an everyday companion for the user who trusts on it as a supporter for activities that provides useful suggestions tailored on individual actions and need. The proactive system is a digital symbiont that knows its owner and act and react accordingly. Among many possible examples, entertainment apps are highly proactive services that use individual preferences to extract information and so actively suggest tailored content to the user. Fitness and workout apps (Balsalobre-Fernández et al., 2017) work on the same principle using individual body parameters and goal setting to suggest actions to the user. Personal information can also be involved in the improvement of already existing functions making them faster, more reliable and personalized. The use of fingerprint detection and face recognition for fast authentication has improved several existing services enabling seamless interactions such as for home banking accesses, fast payments and smartphone and security unlocking.

Moreover, the knowledge extracted from personal information, is a valuable element not only for the user and the service provider. This knowledge, in the form of awareness can support decision making processes as well as contribute to functions also for third party service providers and other involved stakeholders. As examples, the knowledge coming from users’ lifestyle behaviors and bio-parameters can contribute to progresses in health research as well as the tracking of people’s everyday activities can support the creation of smart city practices and policy creation.
3. Personal data as a critical element

While creating services that rely on the use of personal data as core or additional matter for the service, providers are focused on the opportunities that the use of such data offers to improve functionalities. However, many concerns raise in the society regarding the possible consequences of the use, the share and the spread of personal data. When it comes to regulation and policies, the majority of the effort is spent on considering privacy concerns. Being information meaningful with respect to data, people are less willing to give away their data when they realize they are also providing the opportunity to extract information from it. The main concerns on privacy and use of personal information is related to the user’s lack of trust in the company that is collecting and using the data (Joinson et al., 2010).

Considering technologies as non-neutral elements (Winner, 1980), this paper aims to raise awareness on the other possible consequences that the use of personal information could raise on individuals in a complex and connected society. The practices of tracking data and returning knowledge to the users impacts on individuals on different layers. Here I formalize the four layers of the identity that can be perturbed. These impacts have the power to change not only the way individuals perceive themselves and the world, they are able to affect the way the technological solutions will evolve as well as the social practices and the trust people have in companies, institutions, and professionals (Young, 2013) (Schneier, 2016) (Pillan et al., 2017) (Colombo, 2018) (Varisco et al., 2017). I define as ‘impacts’ all the consequences that the use of personal information has and could have on the individuals considering both positive and negative outcomes.

3.1 Data impact layers

**Awareness.** The users receive feedback from the service in the form of visualization of real-time and historical monitoring, patterns and anomalies, personalized goals and automatic setting, notification and alerts thanks to the automatic evaluation based on comparison to references, standard or average. This feedback impacts of the individuals self-perception altering the way they feel about themselves, the way they perceive their identity and increase self-knowledge (Li et al., 2011). Active or passive self-tracking allow users to increase self-awareness about their behaviors, activities, performances, and body parameter and health status (Neff & Nafus, 2016) creating self-mirroring in the provided information. While increasing the knowledge, the visualization of historical data, real-time status as well as possible projections of future trends thanks to AI predictions allows an effortless and seamless monitoring that perturb the self possibly in positive and negative ways. Especially for medical feedback, the way information is automatically return to the user as well as its amount is a critical matter. According to self-perception theory, the returned feedback implicitly reflect the individual perception as a result of personal self-observable behavior (Bem, 1972). In glucose level monitoring systems for diabetic people, for example, the return of information about real-time or historical glucose level has to be consistent with the user ability to understand it and at the same time has to consider emotional aspect of diabetic
people so to avoid unnecessary distress. Patients with diabetes have depressive and anxiety symptoms, such more than general population due to psychological factors such as coping and locus of control (Mućko et al., 2005). The act of being aware of some knowledge has a sort of placebo effect on the individual. A recent study confirmed that the knowledge of individual risk (the study considered DNA analysis for health risks evaluation) affects the personal physiology even if the risk is not true (Turnwald et al., 2019). The practice of profiling individuals such as in the case of behavioral targeting and social labeling for marketing also alter the awareness of individuals. Considering that people are labeled according to their behaviors, beliefs or personality, by receiving a targeted advertising the individuals project themselves in the type of persons the ad is directed to, perceiving themselves according to an external source (Summers et al., 2016).

**Actions.** Proactive services lower the load on humans in making decision triggering actions according to the understanding extracted from computed data. The interaction between the user and the service, mediated by personal information, enables faster, tailored and meaningful tasks completion and service functions. Biodata such as fingerprints and face recognition empower current fast and seamless authentications for unlocking smartphones, for digital payments and for fast access to services. Furthermore, user’s information can enable useful and meaningful micro-interactions such as the use of face proximity recognition for automatic adjustments of tones’ and audios’ volume in order to be less invasive when the user’s ears are close to the phone (Attention Aware, 2017). The eliciting of self-awareness through returning information and feedback also has an agency on people actions and behaviors. The mechanisms related to behavior change such as the feedback-loop are supported and empowered by the monitoring of actions and activities. Altering the user’s awareness about status and performances, the visualization of information sets the bases for modifications in the actions performed through the creation of self-understanding. Then the user reacts to this understanding and to the engagement provided by action triggers such as goal settings and personalized experience and tailored suggestions. The result of this engagement is a change in the single actions performed and even in whole behaviors and attitudes (Neff & Nafus, 2016). By logging data about food eating and even by automatic detection of food intake, users can monitor and develop self-understanding about their own lifestyle and modify their eating behaviors according to the information received. The more types of different data are considered for the elaboration of feedback, the more complex and accurate the tailored experience can be. If the user tracks eating habit together with exercises and performed activities, and the related health parameters, a comprehensive service is able to offer tailored suggestions or nudging to improve behaviors toward a better lifestyle. Considering personalized advertising not only for its impact on self-awareness as a mirror of the identity but also on the point of view of the changes in performance of actions, it has been invented so to have an impact on purchase behaviors way more than untargeted advertising.
**Relationships.** Considering that “the convergence of social physical and virtual spheres of human life has boosted a transformation on the interaction of individuals with their environment” (Aranzabal et al., 2013), we can extend the concept to the interaction between individuals that inhabit this environment being it physical, digital, augmented or intelligent ambients (Gunnarsdóttir & Arribas-Ayllon, 2015). By sharing information within the Internet or among users that take part to the same digital community, individuals can alter their own public images and acquire knowledge about other people. These public images are made out of personal information creating an extended self that multiplies virtual identities and data doppelgangers adapting to the type of service (professional network, health monitoring, recreational network, and so on) and according to the community where the interaction takes place. The data doppelgangers affect the perception that individuals have each other perturbing the interpersonal relationship that occurs among the close circle (family, close friends, relatives, partners and other individuals significantly close to the user in an intimate relationship), the trusted network (friends, acquaintances, colleagues, and other people in which the user trusts at different levels and for different purposes), and among professionals (doctors, employers and employees, and other people with whom the user has a more formal relationship). Moreover, thanks to ubiquitous connected services, knowing people through personal data is today easier than before. As an example, on online dating platforms, people represent themselves to find personal matching. They can meet, chat and know each other through their online personal representations with a very intimate purpose. Personal information is now broadly used also to provide professional services that rely on technologies and connectiveness. Data and information about people, impacts on the relationships people have with doctors, insurers, employers and many other professionals changing the paradigms of entire services. Digital care services and genome analysis, enable new types of interaction between doctors and patients (Lupton, 2013). Doctors no longer have to see the patients in person, they can remotely review patient’s record and monitor parameters. Moreover, patients can access personalized healthcare services according to their information and receive tailored assistance directly from automatic systems. In the case of personal medicine as well as for online dating, however, the provider has to consider that, even if the solution facilitates and supports the service, the personal and physical interaction has a high psychological involvement that could not be properly transferred in the digital remote interaction.

**Social agency.** From active commitment to passive data providing, information about people impacts on their societal contribution in both conscious and unconscious ways. Personal data pass through behavioural analysis, pattern recognition, real-time monitoring and aggregated data analysis to extract information of all sorts aiming at shaping the society and the environment the people live in. Collective values shared among the society reinforce users’ willing to disclose their data for societal improvements fostering public participation in publicly sharing their personal data for the greater good. The voluntary donation of health information such as EMR and genome analyses can contribute in terms of source of knowledge for medical and pharmaceutical research (J. H. Frost & Massagli, 2008)
Going beyond the problem of privacy: individual and social impacts of the use of personal information in connected services. (Weitzman et al., 2010) (J. Frost et al., 2011). The impact that the use of personal information has on the personal societal contribution applies not only to medical research, but also to people’s participation in the society as citizen and actors of their community. In modern cities, people are nodes of the augmented infrastructures. Their actions, reaction and proaction shape the surrounding environment of ubiquitous connected systems of sensors and actuators. Municipalities, private and public companies, and independent entities create urban services, neighborhood, and entire cities that are designed, organized and built starting from data collected from citizen in a mutual exchange of services and social values (Goodchild, 2007) (Mitchell, 2010) (Ratti, 2010) (Chourabi et al., 2012). The social and infrastructural environments act and react according to their inhabitants and connected services take advantage of people’s information to improve and adapt according to historical data and real-time monitoring. The approach of smart cities built ‘from the internet up’, needs constant stream of data to provide reactive and proactive public services and all the decision are made according to the received information. The use of personal information for societal purpose applies also to social policies, safety, justice and law making. Artificial Intelligence can analyse surveillance cameras’ footage in real-time to extract valuable metadata aiming at improving traffic monitoring, capacity planning at shipping ports, and even detecting and reacting to emergencies. AI, as an interpreter of people’s records, is now broadly used in USA as a decision-making supporter for justice and safety impacting on people’s freedom. In order to gather data for social purposes, people are so constantly monitored, even without having a real consciousness of the different moments of tracking and sharing of their data, and of the consequences that their contribution in terms of personal information will have in the societal organization. People’s preferences, historical activities, real-time and everyday data are collected to shape service experience and to create personalized contents. These filtering of experiences and contents provided by services, impacts on the user’s representation of the external world and so on their societal perception.

Consistently with the description of the four layers, Figure 3 shows how the different mechanisms that involve the use of personal information and the derived knowledge, involve more than one layer of impacts, so the four layers have to be considered as linked and communicating rather than separated each other.
4. Conclusions: personal data use as a matter of design

Design is a complex task for complex problem solving. Designers have to cope with the complexity of the world (Norman, 2011) to find solutions to problems so to create a more functional world. Problem solving through design is however utopian. While solving a problem, designers have to face with the uncertainties related to the unpredicted factors that could intervene in the functions of the designed artifact in the moment it is released in the social construct it is built for (or when used in different contexts). Designers cope with the balance between understanding and simplification.
New services and innovative solutions bring changes that can be perceived as utopian to somebody, and as completely dystopian to somebody else. In the creation of such innovative services, designers face with the multiplicity of different perspectives about wellbeing, sustainability, and social justice; they should orient design choices embracing both the contradictions implied by the changes they can produce, and deal with the complex issues that goes beyond utility. While designing digital services, we deal with the inconsistency, variability and variety of the human perception; we should explicit and focus the tangle of issues involved in the use of personal information, so to better understand what is at stake. In the physical world, material tools are open to different uses. As an instance, a blade can be employed to prepare food, to heal injuries, to shape materials for the creation of artefacts, and also as a weapon. In the same way, connected objects, environments and services opens to different uses of the information.

The design of service that implies the use of personal information is a critical task and there is a need of critical thinking in the design of such solutions. Designers have difficulty in figuring out and so be aware of both how and when personal information is implied in designed solutions as well as of the potential impacts that the use of such information could have. While designing connected services that employ the use of personal data and the related extracted knowledge, designers are aware of the importance of the management of personal information mainly with respect to privacy (Varisco, Pillan, et al., 2019), there is a strong need to increase their awareness about the variety of the impacts of the use of personal information while keeping them focused on the utopian goal of improving a specific experience. This need of critical thinking and fostering of the discussion among the design community has the specific purpose of helping designers in creating more robust, consistent, reliable and resilient solutions for the benefit of the company that is providing the service, for the user who is taking advantage of the provided service, and for the whole society as a final target of the advancement of technological solutions. More thoughtful design choices take into account not only the user’s right regarding privacy and security, but also: i) the perturbation in self-perception and self-awareness due to self-mirroring into data and feedback received by the service; ii) the automation of the extraction of the knowledge about individuals as a possible agent on changes on people’s cognitive load, actions and behaviors; iii) the alteration of people’s quality of life, freedom and accesses to services thanks to increasing availability of services that imply personal data as a matter from which extract knowledge; iv) the changes in individuals’ participation in the society and the community and in their interpersonal relationships and roles.

Designers have an active role in designing innovative solutions and their aware design choices can produce an active contribution to the individuation and interpretation of users’ needs and rights about the management of their data.
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Human and Artificial Intelligence for the Cultural Reform of Design

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Abstract | What was once a science fiction topic, now has become reality. We are witnessing the positive trend of robotics and Artificial Intelligence technologies, abandoning specific fields of experimentation and bringing benefits to entire society. Design compares itself with technologies highlighting potentialities and limits in order to define the meeting between human and robot, suggesting new project scenarios and expanding the boundaries of what can really be achieved. Starting from the “logics” of robotic systems, the paper investigates the complex relationship between human and technology in order to encourage the link between Artificial Intelligence and cognitive-relational factors, promoting the dialogue between the actors involved with human at centre of issues as ergonomics, usability and accessibility of robot. Design discipline, with interpretation of needs and interdisciplinary approach, will emphasize the need to use Artificial Intelligence in creative processes and to “humanize” the machine system to define hypothetical relationship between human and robot.

KEYWORDS | ARTIFICIAL ABILITIES, COMPLEXITY, HUMAN BEHAVIORS, MACHINE EVOLUTION, HUMANIZATION
1. Robotics and Artificial Intelligence for the definition of new future scenarios

The unstoppable spread of technologies such as robotics and Artificial Intelligence redefines the future of the interdependent society of intelligence systems expressed by machines that will impact everyday life and change the way we live and perceive our surroundings.

“Education in the proper use of technology presupposes an ethical culture, as well as a scientific-technological one, without which humanity is unable to manage the results of its own knowledge.” (Cingolani & Metta, 2015, p.45)

This will inevitably lead to the need to think about the transformative impact on society because the human of the future will have to interface more with intelligent robotic systems.

Initially the object of industrial applications, robotics represents one of the main innovations that the digital transformation is determining in the organization of social as well as productive processes in which human-machine interaction imposes new design challenges.

In particular, the current scenario shows the presence of people and machines that collaborate together in order to achieve jointly a goal: improving the quality of life through the synergy between human abilities and the “attitudes” of cutting-edge technological systems, generating new forms of secure and flexible collaboration (Vicentini, 2017).

In parallel with the diffusion and pervasive use of robotic technology in the different application fields, the processes, the actors involved and the related skills to be deployed change. Artificial Intelligence, understood as a resource to exploit (Chiriatti, 2019) and not as a threat, represents the innovative potential of the design discipline for the identification and definition of new design processes.

“If we look at robotics as a global opportunity for the human being, on which to invest ideas and resources, we could modernize and make more efficient our welfare, improve the quality of products, making work less dangerous, create a new professional and manufacturing chain. This is the approach we have to adopt. The human sciences can play an important role in this evolution: in order to establish the right role of robots in the future society, to identify risks and to direct research in the most useful directions for humans.” (Cingolani & Metta, 2015, p.51)

Robotic technology and Artificial Intelligence systems, which have become increasingly present as an integral part of everyday life, as well as being more accessible in economic and employment terms, represent the future and the way to continue the process of evolution and definition of the needs of mankind, in order to identify new frontiers of interaction.

Thanks to the continuous use of new technologies, new forms of intelligence are spreading that generate changes in human behavior, attitudes and perceptions. Through the use of Artificial Intelligence, the potential developments in technology, the expected technical
challenges, the opportunities to be seized and the ethical, economic, political and social problems to be addressed are determined.

Artificial Intelligence, one of the major drivers of innovation that has emerged in last years, is not a recently developed discipline. It was born after World War II, with the advent of the first calculators considered as tools able to “reproduce” the human mind and concurrently with the research project proposed by J. McCarthy of Dartmouth College and other representatives of university centers whose main objectives were to focus the in-depth studies on the describable and narrable intelligence of machines.

“Since the mid-1950s several researchers realized that computers are not only number manipulators but can also handle symbols of a general nature, performing non-numeric operations. At that time, several attempts were made to transfer the ability to perform intelligent operations to machines.” (Lerda, 2002, p.7)

It is an area of multidisciplinary research in constant development rich in ideas for advanced research that over the years has consolidated important results in the design of robotic systems and in the field of Human-Robot Interaction, to the point of:

“systematizing and automating certain intellectual activities, and [applying] it to every sphere of human thought. In this sense, it is a truly universal field.” (Russell & Norvig, 2015, p.4)

Therefore, the challenge is to identify ways in order to make the best use of the potential of new technologies in the various areas that are at a mature phase until become a priority for the definition of innovative processes. This is not an easy challenge that sees robotics as a tangible and reliable tool for improving quality of life.

“this shows that the correct and conscious management of these resources can help to optimize the status quo of human beings without excessive distortion and evolutionary risks.” (Cannito & Palumbo, 2019)

The positive intuition in the use of such systems defines the current paradigm shift and reinforces the importance of combination of design and Artificial Intelligence by translating technological innovation into design concreteness.

“Artificial intelligence is not just a new technology that is developing with extraordinary speed. The roots on which it feeds have spread like wildfire around the world, [...]. We must understand that Artificial Intelligence is no longer an option that can be deactivated, a switch that we will still have the ability to turn off. It has become indispensable.” (Alexandre, 2018)
2. Humanization of robotic technology


“We will see more and more things done to Artificial Intelligence, and in the meantime, costs will fall, results will turn out better, and our lives will be better. Soon there will be countless pieces of Artificial Intelligence working for us, often behind the scenes. They will help us in fields ranging the trivial to the substantial to the epochal.” (Brynjolfsson & McAfee, 2015, p.100)

This is a futuristic and sometimes boundless prediction, but it is undoubtedly the direction that research in the field of Artificial Intelligence is taking through an optimistic approach, aware of benefits and opportunities arising. Machines with “super-human” performance, able to act humanly to the point of empathy with the human being. Current robotic systems are intelligent machines designed to reproduce human behaviour and to “support” human intelligence during the performance of activities, in order to optimize human – robot collaboration and at the same time to amplify cognitive and sensory capabilities as well as physical (New Scientist, 2018).

“I would argue that through our use of technology we in fact, are attempting extend and transcend our emotions by way of robot and other intelligent technological agents.” (Tettegah & Noble, 2015, p.53)

In the Human - Machine Interaction, that is continuous, constant and evolving, through the use of Artificial Intelligence, the “instrumental” support for man becomes technology and not vice versa, so as to highlight the concept of “increased humanity”, of innovation at the service of man that can increase the potential and improve the quality of life.

“For this reason [it is preferable] to talk about "increased humanity" rather than Artificial intelligence, in which human potential is improved rather than hindered it. It is fundamental that we learn to use Artificial Intelligence in order to integrate and to improve our abilities instead of trying to compete with it.” (Arienti, 2018)

The importance of the topic of “humanization” of technology is currently among the most discussed in the field of design and engineering. Different are the examples of robotic solutions that transform science fiction into reality, through Artificial Intelligence systems.

As part of these innovative systems, the first case study identified in this research has been Sophia Robot, equipped with artificial intelligence systems connected to the Internet and developed by the robotics company Hanson Robotics.

In detail, Sophia is able to interact naturally with human beings, answering questions and remembering conversations previously held thanks to the infinite database of information that it “updates” by learning from the surrounding environment. This humanoid robot is
modelled on Audrey Hepburn's traits and shows its reactions and responds to stimuli through about 60 facial expressions.

Covered by a special silicone rubber similar to human skin, the robot interprets human expressions through two micro-cameras installed in the eyes in order to establish a visual and empathic contact with the interlocutor.

It is a project born from the combination of science, engineering and art and represents the future of Artificial Intelligence and robotics, to be defined as “hybrid human-AI intelligence” (Figure 1).

Another relevant reference for this topic is the exhibition “Affinity in Autonomy”, presented by Sony Design for the first-time during Milan Design Week 2019 and subsequently at the London Design Fair 2019, in which the relationship between human, emotions, artificial intelligence and robotics has been “brought to light”.

Visitors have been able to experiment and interact with robotics, through five different spaces, exploring the ways in which technology enriches the lifestyle through the emotional links between man and robotics thanks to the developments of Artificial Intelligence.

It is an interactive exhibition that offers a glimpse into the future of Artificial Intelligence for the creation of fundamental and positive emotional connections with humans, imagining a world in which intelligence, technology and creative design are more integrated and define the relationship between human and technology through a deep understanding of Artificial Intelligence and the ability to show emotions (Figure 2).

A further good example is the Project called Neon presented by Samsung at Consumer Electronics Show 2020, a human-artificial being designed on a computational level that assumes human behaviours such as the ability to show emotions, to communicate affectively with the human being, to learn from experiences and to form new memories.

They are real autonomous digital avatars with human features able to dialogue and support the human being in the performance of specific tasks. Each “Neon” can be customized on the basis of physical characteristics, starting from the images of a human being taken from a video camera and replicating on video the same expressions (Figure 3).

“More than a machine and less than a man [...]. Therefore, a mixed society made up of humans and humanoids represents a cultural, social and anthropological challenge, as well as an immense scientific and technological challenge. It needs clear and defined rules and principles. First of all, humanoids have to be human-centric, i.e. they have to be at the service of man.” (Cingolani & Metta, 2015, p.53)
Figure 1. Sophia Robot represents a framework for cutting edge robotics and Artificial Intelligence research, particularly for understanding human-robot interactions and their potential service and entertainment applications.

Figure 2. Pendulus is an interactive robotic pendulum in Affinity in Autonomy that portrays the independence of robotics using random movements and detects human presence engaging visitors and retracting emotion and sensitivity.
3. Human-robot interaction for secure collaboration

Despite the enthusiasm in favour of robotic innovation and the rootedness of Artificial Intelligence, there are many critical issues that influence the adoption of the technology and the real success of the implementation.

“For all these reasons, the strategy for Artificial Intelligence has to develop on two synergistic levels: on the one hand, it is essential to innovate, experiment and thoroughly evaluate the application of the state of the art in AI and data science in all productive, scientific and social sectors, but this is not enough. On the other hand, research efforts need to be stepped up in order to tackle the open problems.” (Pedreschi, 2019)

One of the main factors that represent such criticalities is found in the Human-Robot Interaction, which has only recently become a disciplinary area as part of the Human-Machine Interaction, leading to the need to define new and better “relational” human-machine forms through the multidisciplinary effort that brings together the skills of different professional figures such as engineers, psychologists, sociologists, designers and artists.

The Human - Robot Interaction studies introduce great changes in robotic research that identifies the role of the design discipline through the creative strategic approach and the configuration of innovative scenarios. These studies are needed to investigate human-machine interaction and communication between a robot and human being through human-
friendly way. Human-Machine Interaction has always been one of the main themes of the design discipline. Donald Norman claims that:

“this area of research is experiencing a real boom. [...] Designing real autonomous robots able to interact with people is very difficult; moreover, the social aspects of interaction, including the need for common ground, are much more complex than the technical aspects, and this aspect is often forgotten by the enthusiasm for technology.” (Norman, 2007, p.157)

Thanks to Artificial Intelligence, robotic systems are able to grab objects, to manipulate instruments and make movements once unthinkable, as well as to recognize the surrounding environment, to communicate with humans, to transmit data to other machines, reason, react and to reproduce behaviors, machines that are able to perform tasks and have relationships with other robots and humans, with decision-making autonomy and communicative “mediators”. All the skills that characterize robotic systems include the possibility of contact between system and man and for this reason in the design processes

“Designers must be generalists able to innovate across several disciplines and, in turn, able to turn to specialists to help them develop their design, and to make sure that each component is adequate and functional. [...] Creating intelligent machines means creating interactions, symbiosis and cooperation, both with people and with other intelligent machines. [...] The future confronts our design with new needs.” (Norman, 2007, p.167)

Human - Robot Interaction is based on the concept of safety, especially in the case of contact between humans and the countless collaborative robots present in today's industrial environments during the performance of tasks carried out in a synergistic “mode”.

A robot capable of creating symbiotic relationships with the human being in domestic and work environments needs to be equipped with intelligent devices and external perception sensors that help in case of unpredictable dynamics allowing to “see” and respond adequately to the different situations.

“The objective to aim for is a Human Artificial Intelligence aimed at the benefit of the human person both individually and socially, systems that incorporate European ethical values by design, which are able to understand and adapt to real environments, to interact in complex social situations, and to expand human abilities, particularly at the cognitive level.” (Pedreschi, 2019)

In addition to safety through the presence of integrative systems, another fundamental factor in research on the Human - Robot Interaction is represented by the need to implement the regulatory framework, which is currently insufficient if we consider the strong development and application of multiple robotic and Artificial Intelligence technologies. Systems based on Artificial Intelligence and machine learning have become part of everyday interactions generating a disruptive impact in different sectors, in order to represent the turning point that will progressively change design methods and activities.
For all these reasons, it will also be essential to “reformulate” the regulatory framework, which is currently limited compared to the exponential spread of robotic systems and Artificial Intelligence.

In this context, it is worth mentioning ISO TS 15066:2016 Robots and robotic devices - Collaborative robots, which is currently the main normative reference for collaborative solutions in the industrial field, specifying the technicalities of physical human-robot interaction. From the study of this Technical Specification it has been possible to understand the urgent need to “enter” the field of robotics identifying the points of contact with the discipline of design through the ergonomic approach as the key to understand the technological complexity in order to govern the factors related to safety in the interaction between man and robot.

Design will contribute to the definition of the appropriate design responses of robotic systems through the synergy between multidisciplinary knowledge, outlining new trajectories that provide unexplored fields of action and spaces for the study of physical and cognitive-sensorial interactions for the configuration of robotic and Artificial Intelligence solutions based on ergonomic factors and Human-Robot Interaction.

Current research is also able to develop appropriate interfaces that allow interaction and communication with natural, intuitive, multimodal and human-friendly features.

4. Design and Artificial Intelligence in creative processes

Artificial Intelligence technologies in design are used to bring broad benefits to this sector. Today the technology not only integrates with project, but it simplifies every process in the industry in order to be so helpful in solving problems playing a central role at every stage of development.

The design goes through a phase of change in which it becomes “contaminated and technologized” thanks to the ability of hybridization that allows to identify new possible scenarios. Design becomes a meeting point between the technological innovations and everyday life in order to reduce complexity and to highlight the actual needs of users.

“Machines may become self-aware, humans and computers with processing capabilities may merge seamlessly, or other fundamental transitions may arise.”

(Brynjolfsson & McAfee, 2015, p.267)

It will be necessary to hypothesize robots and machines able to perform the tasks carried by humans, moving from the automation of repetitive tasks to making complex decisions, so as to create innovative opportunities “offered” by Artificial Intelligence.

“In a nutshell, current Artificial Intelligence looks smart, but it’s an artificial resemblance. This situation may change in the future. One day we could start making digital tools that mimic our minds more faithfully, perhaps even using our rapidly
improving scanning and brain mapping abilities. And if so, these digital minds will surely enhance ours and may even eventually merge with them, or become conscious.” (Brynjolfsson & McAfee, 2015, p.268)

Thus, the use of Artificial Intelligence will accelerate the process of innovation and growth, rethinking and transforming the social and productive system through the collaboration between human and machine, which will give new shape to the markets and to the society.

So, the real strength of technology lies in being able to amplify human abilities, “co-creating” with Artificial Intelligence in order to define forms of creativity between art, science, engineering and design.

Figure 4. Symbiosis between design and artificial intelligence for innovation in creative processes and humanization of machine.

The role of Artificial Intelligence in design processes will not be “reductively” of “generating” products through algorithms and generative systems based on Artificial Intelligence. This factor will and will continue to be part of change, an

“emerging model of symbiosis between human and machine [that] is unlocking what we have called the third wave of industrial transformation.” (Daugherty & James Wilson, 2018, p.18)

The transformation of the design world will lead to a reformulation of design approaches and methods that will require greater efficiency, a reduction in the possibility of errors in human-robot interaction and a special attention to experience that is as human as possible. From the 1970s onwards, the discipline of design has been observing people and specifically
behaviour in order to capture and to interpret the story and therefore the needs, generating
direct involvement in the design process. User Centered Design is part of this context.

In particular, the application of Artificial Intelligence technologies will innovate the sector in
the field of Experience Design in order to focus attention on the design and quality of the
process and experiential factors during user-product interaction. The roles and skills to be
deployed will also change, “while creating new professional profiles related to design,
control, maintenance and advanced manufacturing” (Cingolani & Metta, 2015, p.50).

Robotic systems able to have social relationships with other robots and human beings are no
longer scenarios of the future as robots and people already interact with each other to
improve business processes and quality of life.

“Today the use of robots goes beyond mere manufacturing activities thanks to the
convergence of a series of technical-scientific disciplines that have reached a degree
of maturity that allows the creation of a new generation of machines equipped with
a strong artificial intelligence and sensory organs that make them suitable to interact
autonomously with human beings and the surrounding environment, be it a factory,
an office, a private apartment, a battlefield or a highway.” (Forni, 2016, p.5)

The real potential of Artificial Intelligence lies in the new possibilities offered by the
increasing humanization that renews and redefines the boundaries of the design process. If
in the past man had to adapt to technology, in the current scenario, technology will have to
be controlled by man, interacting with human rules in order to determine the technological
innovation that comes from the design of machines for people.

What seems certain is that in the era of emotional connections, the new humanized systems
based on Artificial Intelligence, represent the future and the "context" in which to
experiment and formulate new rules for the cultural reform of design.

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Human Sensibility, Robotic Craft: Toward Autonomous Stonework

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Abstract | Recent advancements in architectural robotics allow designers to explore the coupling of traditional craft with digital tools. However, current methods remain limited in capturing the qualities and nuances in manual techniques. The paper presents a protocol for transferring traditional stonework to robotic fabrication, aimed at supporting future autonomous manufacturing. The protocol re-instills the qualities of manual stonework in contemporary architecture by employing advanced sensing and fabrication tools. The paper presents three capacities, drawing upon historical practices and current standards: documenting - recording and analyzing stonework techniques; augmenting - enabling to reenact the craft using a robotic arm, and enhancing - a proposed framework for autonomous robotic fabrication in uncertain conditions. In the face of the demise of manual work, these new avenues for robotic fabrication assist in preserving and advancing regional stonework.

KEYWORDS | COMPUTATIONAL DESIGN, DIGITAL FABRICATION, TRADITIONAL CRAFT, STONE CARVING, FEEDBACK-BASED AUTONOMOUS MANUFACTURING
1. Introduction: Digitizing Craft

Craft is defined by an intimate relationship between the craftsman and the material at hand (Pye, 1968). The rise of automation in the recent century is associated with the demise of craft and the replacement of manual work by industrial manufacturing (Giedion, 1948). The introduction of digital fabrication presented the opportunity to reconnect design conception with the making process, marking a return to craftsmanship in what is often termed ‘digital craft’ (Kolarevic & Klinger, 2008). However, in practice, digital fabrication has only limitedly bridged the distance between the designer and the artifact (Mindrup, 2015).

Researchers formerly explored practices for digitizing stonework in the context of historical restoration. Amongst these practices are CNC sandstone milling to reconstruct sculptural stone façades based on 3D scanning (Hayes, Fai, & White, 2014), and restorative stone sawing by industrial robotic arms of columns in the Sagrada Familia (Burry, 2016). While both present a novel approach to digital stone fabrication, their focus is on form-production rather than the traditional technique used to create the original elements.

Decoding traditional techniques is elemental to transferring craft from humans to robots. The use of motion-capture technologies is explored to enable this. This practice relies on recording skilled workers to produce an initial database for digital fabrication protocols (Bard, Blackwood, Sekhar, & Smith, 2016). While researchers previously explored this technique on stonework, they focused on documenting single tool-strokes, with little regard to traditional finishing techniques (Steinhagen et al., 2016). However, a process cannot be generalized from a single stroke. As far as manual carving is concerned, the distance and the relative angle between strokes is as defining as the stroke itself. Also, each tool is operated uniquely. Therefore, data derived from one tool recording does not apply to the operation of another. Expanding the scope of motion capture to include an array of specific techniques and their respective tools can help create a robotic fabrication protocol for multiple tools as well as for a multi title of material conditions (Figure 1).

Figure 1. A detail of a robotically produced element based on traditional carving techniques.
2. Paper Structure

This paper presents a robotic stonework protocol towards an autonomous fabrication process, explored through regional stone practices. It describes the current status of digital craft and provides background for the regional stonework case study in terms of finishes, tools, and techniques. A specific case study is presented, transferring craft from human to robot. Two capacities are demonstrated in this regard - documenting particular techniques and augmenting them to robotic fabrication. Enhancement, an autonomous stonework procedure, is presented as a future avenue for research.

3. Case Study: Regional Stone Craft

Stone holds a central role in Mediterranean cultures and Israeli architecture, in which stonework represents a primary craft. The predominant stone types used in Israel are dolomitic limestone, all originating and mined in the area (Perath, 1984). Historical research refers to the use of stone alongside a range of carving techniques and chiseling tools (Shadmon, 1972). The Jerusalem master plan protects this longstanding tradition, providing guidelines for the application of stone in the city. The guidelines specify that: “The outer walls and pillars of houses will be covered with natural, finely dressed stones.” (Jerusalem Municipality, 1959). Stone related guidelines are also part of the Standards Institution of Israel, which defines the characteristics of various stone dressing techniques for cladding (Figure 2). These regulations highlight the continued significance of stonework to the region.

Despite the specificity of the standard in terms of the stone dressing’s appearance, and the centrality of stone in the local context as reflected in the literature, research does not directly refer to the specifics of stone dressing techniques. Historic documentations shed light on this aspect, as they depict stone processing tools and techniques used in the region. Conrad Schick, a 19th-century German architect and archaeologist, includes sketches of the chisel marks on the Jerusalem city wall believed to be carved in ancient times – circa 2500 BC (Figure 3).
The sketches are accompanied by textual descriptions, detailing the general measurements and geometrical features of the carving:

“They are nearly straight strokes exactly parallel, and 3/8 inch distant one from the other, vertical, but to some degree sloping, and sometimes forming a slight curve, so that one row of them meets another at a sharp angle. They are not deep, but from 15 to 18 inches long, and so arranged as to form layers one above the other.” (Schick, 1891)

However, when Schick attempts to classify the techniques, and in lack of familiarity with the local culture and language, he refers to chisel strokes as “flaking” and “pocking” and to patterns as “irregular,” overlooking the essential characteristics of each technique. In this context, almost a century ago, the Palestinian Physician and Ethnographer Taufiq Canaan documented local tools and methods, addressing the imminent extinction of traditional architectural stonework in the face of modern building technologies (Canaan, 1933). Canaan’s ambitious work documents stone building processes and describes the tools in use (Figure 4). However, it is limited in its ability to convey the actual technique - namely, the specific hand gestures enabling them. This form of tacit knowledge foregrounds technique over expression (Sennett, 2008). While this technique previously resided in the human mind and hand, it can now be transferred as operational instructions to technological tools (Shaked & Dubin, 2019). Hence, the relevance of digital methods in documenting and augmenting traditional craft.

The protocol allows transferring manual craft to robotic fabrication following three capacities: documenting, augmenting, and enhancing. These capacities are demonstrated through a regional stonework case study.

4.1 Documenting

It is possible to link stonework products with the techniques and tools that enable them by drawing on the historical accounts (Table 1). However, documenting regional stonework cannot rely solely on literary descriptions or existing artifacts. While these depict the technique and tool, they do little in capturing the parameters of stone production. While some of these parameters are visible (tool orientation and stone position), others are either too subtle to perceive (specific entry and exit tool-angles and stroke distances) or undetectable to the naked eye (for instance, stroke force and chisel speed).

Table 1. Carving techniques and their respective chisels.

<table>
<thead>
<tr>
<th>Carving Technique (Figure)</th>
<th>Finish Description</th>
<th>Chisel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taltish (Figure 2, a)</td>
<td>Coarse dressed surface</td>
<td>Pointed chisel (Shawkah)</td>
</tr>
<tr>
<td>Musamsam (Figure 2, b)</td>
<td>Short, fine parallel lines</td>
<td>Toothed chisel</td>
</tr>
<tr>
<td>Tubzeh (Figure 2, c)</td>
<td>Roughly dressed surface</td>
<td>Flat, slightly sharp chisel (Izmil)</td>
</tr>
<tr>
<td>Mattabeh (Figure 2, d)</td>
<td>Finely speckled surface</td>
<td>Bush or granulating hammer</td>
</tr>
</tbody>
</table>

A local craftsman was recorded working to capture the stonework data. The stone used was yellow limestone typical to the region, quarried in Mitzpe Ramon, located at the Negev desert of southern Israel. This stone is primarily used for wall cladding, architectural detailing, and sculpting. Its measurements were standard-sized (25-by-60-centimeters). The set up included a motion capture camera system and a carving table. In parallel, the chisel was mounted with a series of markers to reconstruct the tool’s position and orientation during the carving session. The craftsman performed three traditional stone carving techniques with the correlating hammer and chisel: Taltish, Musamsam, and Tubzeh (Figure 5, Figure 6).
Figure 5. Documenting the three techniques using motion capture. Using the (a) pointed chisel, (b) toothed chisel, and (c) flat chisel (Shaked, 2019).

Figure 6. The respective outcomes of the carving sessions: (a) Taltish, (b) Musamsam, and (c) Tubzeh (MTRL, Technion, IIT, 2019).

An initial calibration session was performed, aligning the virtual and the physical tools. For statistical validity, each technique was recorded three times, producing nine data sets (Figure 7). The captured data includes the essential tool and pattern parameters (such as the chisel speed, carving path, and strokes). In the future, this data could amount to a digital archive of stone craftsmanship, which is particularly pertinent in the face of the craft’s disappearance from the region.
Figure 7. 3D visualization of the three techniques based on the motion capture sessions database. The lines mark the toolpath in space throughout each session. The position and orientation of each chisel are recorded in a 100Hz refresh rate.

4.2 Augmenting

The documentation results were analyzed and translated into robot motion commands to enable augmenting the stonework. The robotic set up includes a KUKA KR60 industrial robotic arm mounted with a custom-designed, multi-chisel carving end-effector. The modular end-effector allows performing various carving techniques using a single end-effector and easily alternating between different chisels during a single carving session. In parallel, a custom application was developed to translate the documentation results to robot motion commands. The application derives the tool’s motion in space from the craftsmen’s gestures and converts them into a robot toolpath.

An artifact titled ‘Augmented Stonework’ is presented. It was created using the information gathered from the Taltish carving session. This information was converted into a parametric carving pattern, which could then be applied to multiple stone sizes and types. A block was then placed on an XY positioning table, and scanned to produce an accurate point-cloud, converted into a three-dimensional virtual model. Following, the carving pattern was projected onto the virtual model (Figure 8). The integrated model, including both the block and the carving design, was then used to produce specific robot commands for forming the object (Figure 9).
Figure 8. Carving pattern generated using the documentation phase data, projected onto a 3D scan point model of the material, and converted into robotic fabrication instructions.

Figure 9. ‘Augmented Stonework’ – A robotically produced element based on traditional regional stone carving techniques (MTRL, Technion, IIT, 2019).
4.3 Enhancing: Future Development Towards Autonomous Craft

Augmenting the craft allows for increased precision and repetition within the stonework process. However, achieving autonomy in craft relies on the ability to contain imprecision and handle variability. In stone carving, the craftsman analyzes the material's state before each stroke and positions the tool accordingly. This capacity for real-time material analysis is elemental to manual subtractive techniques. Therefore, the transference of traditional stone craft into a robotic fabrication protocol can go beyond documenting and augmenting – to enhance stonework with autonomous capabilities. In contrast to automatic processes that enable repetitive acts or motions, autonomous processes can facilitate the adaptation of robot gestures in response to changing material and environmental conditions.

To this end, the enhancement of robotic stone craft will include developing a sensor toolkit and a respective real-time communication protocol. The protocol will enable receiving input data from the external sensors and communicate it to the robotic arm – thus updating the virtual model and altering the initial prescribed motion plan (Figure 10). The received data will be translated to motion control via a series of pre-defined parameters based on behaviors defined in the case study phase. These parameters will determine the appropriate reaction to environmental and material information in terms of the robot’s end-effector location, orientation, and actuation. Enhancing the robotic fabrication process will allow the robot to react to uncertain conditions during the fabrication process. For example, in the stonework case study – this could enable adjusting the chisel position, orientation, and stroke speed during the carving process according to sensory data - regardless of the initial motion plan.

Figure 10. An autonomous fabrication process for dealing with material uncertainty (MTRL Technion IIT).

5. Conclusion

Transferring manual stonework to robotic craft requires a comprehensive understanding of the craftsmen’s gestures and techniques. This need highlights the continuing relevance of
artisanal knowledge in an age of increasingly digitized manufacturing processes. In this context, the paper focused on human-robot regional stone craft transfer. Drawing upon historical records, it highlighted the link between the tool, the gesture, and the particular stone dressing characterizing this traditional practice. It proposed using industrial robots as a production platform and integrating sensory data and manual capabilities into architectural production to enable the documentation, augmentation, and enhancement of manual crafts through advanced fabrication.

Documenting and analyzing a stone craftsman at work was used for capturing this hitherto inexistent data about the specifics of the technique associated with each stone finish. The data then served as a basis for augmenting region-specific methods using a robotic arm. As the case study experiments demonstrate, detailed documentation can provide a foundation for autonomous stonework. Each case study coupled a carving technique and a tool-type, together with the respective robotic platform allowing the automated craft version. The presented protocols and resulting artifacts indicate the possibility to advance autonomous fabrication, not limited to stonework, but also to other forms of craft, as well as with a wide array of materials.

Stonework craft is traditionally passed on from father to son. With the prevalence of automation, the number of skilled workers diminishes, and the craft is on the brink of extinction. The research addresses this crisis by documenting the gestures of local craftsmen at work. The resulting database can be used in the future for historical and cultural preservation, as well as for training new craftsmen. This approach entails a new form of conservation for architectural elements while also providing ways for fabricating them. However, this capacity relies on examining the tools and techniques guiding craft and seeking a greater sensibility in their application. A full understanding of this can, in turn, help establish a more nuanced relationship between designers, robotic tools, and the matter at hand.

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Interface takes command. Educational environments, tools and practices to face the new normal.

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Abstract | The Covid–19 pandemic has underlined the new role of digital experience in everyday life. Nowadays, pedagogy and digital technologies should be investigated in order to educate young people to produce knowledge and not to uncritically consume digital products. The development of digital technologies like AR or VR – applied to teaching and learning – is providing an exciting opportunity to design realistic, authentic, engaging and extremely fun learning environments in a broad way. Because of this, the gap between physical places and virtual spaces seems to disappear. The interface between human and computer is an essential part of this process, providing technology accessibility and new approaches to learning and teaching. By the development of increasingly pervasive digital technologies, it is undeniable that the interface, from its first forms of GUI, to TUI, VR, or AR has become a tool capable to blend the differences between the two worlds – tangible and intangible – looking for a fusion that is very close at the moment.

KEYWORDS | INTERFACES, PEDAGOGY, NEW NORMAL, EDUCATIONAL ENVIRONMENTS, DIGITAL TECHNOLOGIES
Premise

The following contribution intends to provide an overview on the contemporary interface project as generator of environments in the educational field as answer to the new skill requested by the digital revolution society and the new normal after Covid–19 pandemic. In particular, paragraph two presents a theoretical overview and key to understanding the whole contribution; emphasis is placed – on the one hand – on the definition of interface as an environment and design of culture – on the other hand – we focus on the possible effects and potential of mixed reality interfaces in the field of education. Paragraph three – instead – presents a series of best practices related to the educational field divided by the ability of the interface to be a driver of environments or vice versa, by reviewing Tangible Interfaces projects up to immersive learning spaces.

1. Introduction

The Covid–19 pandemic, that has spread over the entire world since the end of 2019, despite being a purely health issue, has inevitably highlighted the role of digital technologies in the life of every single person inevitably (Ting, et al., 2020). If once, the World Wide Web was considered as a parallel world – in the dichotomy between the physical and virtual one – today we should assert the overcoming of this split in favor of a single hybrid world, the information society (Floridi, 2014) and the Mixed Reality (MR) world: a condition in which the digital information are totally pervasive and layered over the physical world (Resmini, Rosati, 2011). The need for social distancing, lockdown and all the prevention and containment measures against Covid–19 have influenced the social, cultural and behavioral aspects of all humanity (Nicola, et al., 2020).

For this reason, pedagogy and digital technologies should be investigated in order to educate young people to produce knowledge and not to uncritically consume digital products. No one can deny that smartphones play a central role not only in our lives but also in children’s one (Maes, 2019). Digital Revolution is gradually changing different aspects of material and immaterial society by the ubiquitous Internet, IoT and ICT (Bollini, Caccamo, Martino, 2019). Nevertheless, as Maes states (2019), we live in an illusory dichotomy between parallel worlds: the tangible physical world and the intangible digital one mediated by a theatrical wall (Laurel, 2013) – the interface – enclosed in the palm of our hand.

On one hand, the traditional pedagogical systems seem to be unable to attract youngsters. Accustomed to look beyond the textbook, they are fascinated by what allows them to enter into the subjects. In order to do this, one of the keys is the use of non–invasive but additive technologies, such as Mixed Reality – AR or VR. The power of these technologies – applied to the environment – is their ability to design functional spaces based on physicality, construction and imagination (Ärlemalm, 2006; Fjørtoft, 2004).

The development of digital technologies like AR or VR – applied to teaching and learning – is providing an exciting opportunity to design realistic, authentic, engaging and extremely fun
learning environments (Kirkley, Kirkley, 2004) in a broad way. Because of this, the gap between physical places and virtual spaces seems to disappear. During the last decades, different pedagogical approaches that combine technology and education have been developed, such as Digital Object Based Learning (Chatterjee & Hannan, 2015), Visual Thinking (Housen, 2002), and Digital Storytelling (Rappaport & Liguori, 2019). All these approaches are characterized by an active involvement of the people. In addition, it should be also considered how the web and related technologies affect the sensorial, perceptual and behavioral relation between children and educational objects.

2. Theoretical background and main concepts

2.1 Interface: a contemporary definition

Due to the strong influence of the disciplines from the Human Computer Interaction, the cognitive psychological to the engineering sciences (Pold, 2005), the concept itself of interface has been declined in its purely functional meaning, i.e., as the tool able to make man and machine communicate in order to achieve the intended task. This approach reflects the will of invisibility that Norman (1990) affirmed as the ultimate goal of achieving perfect affordance, underlining how the interface’s problem is itself the interface (Norman in Pold, 2005). Nevertheless, neutrality is impossible. Because the interface "is designed within a cultural context and at the same time designs cultural contexts" (Interface Manifesto, 2015). This approach can be seen from the beginning of the Graphic User Interface. The interface design has always borrowed the concept of environment, first through rhetorical forms of spatiality – such as the WIMP interface – until today in which digital technologies such as Virtual or Augmented Reality allow interfaces to be designed as environments and to actually interact with the surrounding space. But is the interface an environment?

"we look at interface as a thing, a representation of a computational process that make it convenient for us to interact with what is really happening. But the interface is a mediating structure [...] it is a space between humans and procedures [...] and determinates what can be done in any digital environment". (Druker, 2014, pp.138–139)

Drucker's theory (2014) turns out to be the natural evolution of the intuition that Gudrin (1989) had theorized. Gudrin – in fact – affirmed that different forms of interface – terminal, functional, software, dialogical – and ultimately social have followed one another in history, thus underlining its pervasiveness towards the environment. According to Manovich (2001) and as reiterated within the Interface Manifesto (2015) today we could say that the interface – in a broad sense – has reached the level of Culture, as it is not a mere tool of man–machine communication but has become the main communication medium between men (Johnson, 1997), as well as a tool capable to design culture. More than before – due to the Covid–19 pandemic – we use the interfaces to talk with other people through social media, discuss
about works by Skype and produce culture, for example digital art, books and so on. Finally, we design interfaces by using other interfaces (Manovich, 2010).

From a metaphorical point of view, analyzing the relationship between interface and environment, we could also introduce the terms of movement and corporality in the use of the interface. In general, the design of a GUI or of the UX of a digital product is nothing more than the design of the movements in a given space – virtual or not – of a single or multiple users. Laurel (2013) in this regard, creates an interesting parallel between the interface design and the theatrical project. Analyzing, in fact, it is possible to find at least three points of contact between the theatrical world and the interfaces one: stage / background, interaction, metaphor. Both show a touch point, in which the action takes place (the UI), and a backstage, which supports the structure (the architecture and the back end). From the interaction point of view, this process – in the theatre – can be seen both as the interaction between the actors on the stage and also on the empathic relation between actors and public/user. In the interface world, this process is attributable to the design of the interaction. Lastly – the clearest – theatre and interface, as mentioned, are based on rhetorical systems able to reflect us from one world to another, managing to break down the barrier as long as they are used.

Thanks to the development of increasingly pervasive digital technologies, it is undeniable that the interface, from its first forms of GUI, to TUI, VR, or AR has become a tool capable to blend the differences between the two worlds – tangible and intangible – looking for a fusion that is very close at the moment.

In order to understand the relationships between digital physical and digital environment, it is necessary to mention the "Reality–Virtuality Continuum" scheme by Milgram (1994). The scheme is a scale that moves from a completely real environment up to a completely virtual one. The space between physicality and its virtualization of the environment is defined by Milgram: Mixed Reality (MR). It is the place of interaction and intersection between the real environment and the virtual one at progressive point mitigated by technology. Using Mixed Reality, the hybrid real–virtual environment takes concrete form, and the interface becomes a generator of environments.

The interface is a media (Manovich, 2001), which mediates and filters between data, algorithms, coding languages and humans. It is a cultural action in which we produce culture using interfaces (Manovich, 2010) and form the world. For this reason, the Milgram scheme can be updated with the Mann scheme (2006) in which the mediation value of technologies respect to the environment is highlighted. It is a matrix system that shows the greater complexity of the physical–virtual relationship, compared to a "purely" linear system. We live thought interfaces and thanks to them we communicate, work, get excited, learn and grow (Pold, Anderson, 2018). More and more information will be accessible to us. Only by the use of new forms of MR, we’ll be able to balance the constant growth of knowledge, accessibility and dissemination of contents (Samit, 2019), thanks to an intelligent environment able to communicate with us. Starting from these considerations, it is
Deducible that education could be seen as a fertile ground for the applications of MR technologies.

2.2 The interface as driver for education

Contemporary society – called society 4.0 – is the society of the digital revolution. Increasingly accessible technologies that allow us to open new horizons and new ways of living and experiencing life. A complex society that requires inhabitants to have complex skills accessible to everyone. There is a evident research for innovative pedagogical tools to meet the skills demand of the current and future society. As stated by Fullan & Langworthy (2013), interesting and new forms of pedagogy are taking hold thanks to the intersection of design–technology–education. In this context:

"The interface between human and computer is an essential part of this process, providing technology accessibility and new approaches to learning and teaching" (Starčič, Turk and Zajc, 2015)

In fact, today, we are able to understand and shape the surrounding world by interfaces (Interface Manifesto, 2015). The new digital technologies open up new scenarios and contexts of education that move away from the classroom format (Starčič, Turk and Zajc, 2015), to different, customized and immersive realities, both in term of content and users. Among these, the growing demand for personalized educational supports within museum contexts capable of implementing curiosity, attraction and developing critical thinking through a re–reading of the collections present in museums (Poce, Amenduni, De Medio, Valente and Re, 2019).

Education should be considered the basis of a society that aims to create a better, sustainable, responsible and conscious future (World Economic Forum, 2018). Education is the first step towards evolution. As can be read within the programmatic lines of the Italian Digital Schools National Plan (Piano Nazionale Scuola Digitale, 2015), the introduction of digital technologies in the educational field is first and foremost a cultural action, based on a new concept of school intended as an open space for learning and not just a physical place. In this paradigm, technologies become enabling, daily, ordinary. So, Do MR interfaces enhance education?

Educators who see technology in action immediately recognize its potential to engage, educate and entertain (Parlier, 2019). There is numerous scientific literature that testifies the use of Mixed Reality technologies in educational contexts. Nevertheless, the state of current MR research for education is still in its infancy (Bacca, et al, 2014; Wu, et al., 2013, Cheng & Tsai, 2012). According to (Nincarean et al., 2013) despite of the numerous previous studies have shown a positive impact and encouraging results in the use of MR technologies in the educational field, scientific research must now move towards a pedagogical and learning theory linked to the implementation and development of MR tools. The educational value of digital technologies such as virtual, augmented reality and so on, cannot be based
exclusively on their specific characteristics. Many themes must be investigated in terms of aesthetics, characteristics and peculiarities that these technologies can give compared to other mediums (Bacca, et al., 2014). First of all, the interaction–relationship with the surrounding space. The study conducted by the Computer Education and Instructional Technologies departments of the Universities of Kirikkale and Gazi in Turkey (2017), highlighted the pedagogical role of the introduction of the MR in the band called K–12 of teaching. Within the research work, different AR applications in education were analysed and the potential of new digital technologies has been brought to light. In the report, citing Chang et al. (2014) it is found that AR is able to increase the level of attention towards the topics covered. In another study by Dunleavy et al. (2009) – contained in the Turkish research project – AR technology via mobile device has facilitated collaborative learning in hybrid learning environments. Lastly, Liu and Thai (2013) through a multisensory AR system based on the sight, hearing, speech and movement of the whole body of the students, were able to increase the physical activity of the students by improving their motor skills.

The possibilities offered by these technologies allow to increase the knowledge of traditional supports, which as stated by Sun, Wu, Fan, Dong (2019), are bound to the limits of the two dimensions, favoring instead a third or even fourth dimension, in order to boost imagine engaging, immersive and multimodal learning processes. In fact, the power of MR technologies resides in the local ability to generate environments with latent information and content (Samit, 2019).

“Learning becomes more enjoyable and effective, even when it comes to exploring and knowing abstract concepts or complex phenomena, and this thanks to the possibilities of visualization and realization of the concepts that this technology makes accessible to the learner”. (Klopf & Squire in Elmqaddem, 2019, p. 238).

If on the one hand the need for a tangible experience is highly recommended, at the same time it is required to innovate pedagogical tools capable of making the best use of the power that new digital technologies expect to have. Products and environments developed in MR – as we will see in the examples in the following paragraphs – could become the test of the new way of experiencing a complex reality in a digital society on top of the maturity (Baricco, 2018) made of the info–tangible diversity and the info–intangible one. Therefore, the role of educational interfaces in MR becomes transmitting culture, which in accordance with Bruner (1996) is the "toolbox" given for adaptation to civilization, a way of solving crises and problems.

3. Best practices and state of the art

The interface – as stated in the previous paragraphs – shows capabilities that go beyond mere functionality. It constitutes the main medium of contemporaneity (Andersen, Pold, 2018) and the most important cultural form of our century (Johnson, 1997). The strength of the interface lies in its ability to be multi–media, i.e., in its nature of re–mediation (Bolter,
Grusin, 1999) of classic and contemporary media – texts, images, videos, sounds within a new form and attractiveness. It is no coincidence that we understand how education – driven by the need to innovate its pedagogical protocols – sought to make use of the interface as a pedagogical driver. Education, in fact, places in the interface the value of cultural leverage and promotion of critical thinking, analysis, and in general, of the new contemporary skills.

The interfaces that will be presented in the following paragraphs can be represented by an inversely proportional linear scheme in which the relationship between environment and interface is interpenetrated and modulated. If on the one hand, the Tangible User Interface, have the ability to generate and control a digital interaction environment through the manipulation of reality (Ishii, 2006), on the other hand, multisensory environments and in general the interactive environments make use of the environment itself to become the interface with which the user can interact both physically and emotionally. Both forms start from the consideration of the role of the sense and of the body in the interaction and educational process (Kim & Maher, 2008), demonstrating effectiveness in terms of cognitive impact, improvement of analysis and criticism skills both in standard subjects and in subjects suffering from cognitive disabilities. Movement is an integral part of a child's psycho-physical process. Since "it is not enough to simply accept that play is important in education" (Waller et al., 2010), it is necessary to rethink what it represents for a child to play in the 21st century (Änggård, 2017).

3.1 When an interface acts as an environment

The ifs | 2020

Gaming is a fundamental activity for the solid construction of bases capable of increasing various factors of brain development, both as regard social and communication skills, as well as emotions and cognitive and physical abilities (Mastrangelo, 2009). The ifs is a project currently in the crowdfunding phase, which compared to the following cases is characterized by its totally tangible nature. The educational set has the aim of teaching the basics of coding without the use of digital displays, but by using tactile interfaces only. As we can guess from the name – the ifs – the logic of the game is to convey the concepts of action and reaction – if and then – through the intrinsic perceptual characteristics of the individual robots: sensitivity to sounds, touch, light. By leveraging imagination and creativity, children have the opportunity to learn coding and improve logical thinking, teamwork, creativity and notions of robotics. The robots can be programmed both in the IF condition and in the Then condition, thus increasing the possibilities and combinations of interactions.

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1 [www.theifs.cc](http://www.theifs.cc)
2 [https://youtu.be/AcZlN3hAf6k](https://youtu.be/AcZlN3hAf6k)
Tangiplay | 2019

Computational thinking is recognized as a necessary skill for everyone (Wing, 2006), by virtue of this, there are numerous products that, by an analog / digital relationship, teach the foundations of a new language that is an integral part of the digital literacy of the new generations. Within the range of products available on the market, Tangiplay is certainly one of the most interesting. Developed through a crowdfunding campaign in 2019 and winner of the IF Design Award 2020, the game aims to teach the fundamentals of coding – sequencing, condition, function, loop – using coloured puppets as physical controllers of the activities available on the tablet. Children – from 4 to 12 years old – have the task of designing a railway track capable of going from point A to point B: the metaphor of a code string. The individual puppets – chromatically divided by function – are used as programming elements, defining the route that the train will have to take. When they press, slide, or rotate the robot, this translates into code that creates a unique response in the game. What children do is the logical transcription of an algorithm, understanding the logical basis of the coding language.

Project Zanzibar | 2018

The blending of physical and digital interfaces has the promise of creating more fluid, dynamic, and ultimately engaging user experiences (Spadacini, McDonald, 2017). This is the goal that the Microsoft Research team has set itself in the development of Project Zanzibar, unveiled in mid-2018. The idea of the project is that of a polymeric capacitive platform – a sort of flexible and portable pad – capable of detecting objects, connecting them and perceiving their contact with the user’s hand. The technology behind this project is a combination of capacitive sensing and the NFC protocol, allowing the touch and mouse to coexist with the manipulation and control of physical objects. Every single object present in Project Zanzibar is listed through a unique ID, which is therefore able to keep track of all data – movement, rotation, pressure – thus archiving the history of the individual object. Children use the individual objects on the pad as a tangible interface by manipulating and controlling the related digital avatars on the pad. In addition to semantically neutral objects – therefore capable of being used within the platform without alternating their content – there are semantically active objects, whose presence changes the digital environment. The introduction – for example – of a palm–object interferes in the digital context by changing the scene.

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3 www.tangiplay.com
4 https://youtu.be/QjyzutQUOv0
5 www.microsoft.com/en–us/research/project/project–zanzibar/
6 https://youtu.be/4Gl6iaVXZu0
3.2 When an environment acts as an interface

In Tune with Nature | 2019

Museum systems are among the most active promoters of new technologies related to the learning and use of cultural content (Poce, Re, Amenduni, De Medio, Valente, 2019). Immersive and augmented experiences are now proposed to different target users with the desire to enrich the cultural heritage of the museum itself. Outdoor contexts are re-proposed in a digital key, offering learning opportunities and thematic focuses that are not always achievable through a purely tangible experience. With this in mind, the project created inside the Cayton Children's Museum in Santa Monica, entitled In Tune with Nature, should be read as an immersive room in which experiencing the natural cycles of day and night. The underlying technology is the consolidated projection mapping with motion sensing. Children find themselves projected into different natural contexts, analyzing and understanding the changes in the elements over time. In addition to the interaction factor, the work done—in terms of the visual language of the illustrations—is interesting: combining fidelity of detail with formal dryness.

Interactive Immersive Classroom | 2018

The educational environment par excellence—the classroom—is also undergoing a revolution thanks to the advent of digital technologies (Oke, A., Fernandes, F.A.P., 2020). In fact, we are moving from a purely frontal form of teaching to an "experience" of teaching that involves all the senses to improve attractiveness and critical thinking. This is the mission of Interactive Immersive Classroom, a teacher-friendly system that offers customized experiences for teaching. The strength of the project lies both in the availability of content—opensource library, as well as content selected from streaming platforms such as youtube.com—and in the total immersion of the classroom. The system is also extremely flexible based on the contexts of use, meeting the different architectural settings that arise from time to time within the schools. Designed for the teacher, it becomes an active teaching support for selection—display—validate the teaching content. Furthermore, immersion guarantees a high level of engagement and attention threshold, managing to effectively convey complex concepts, for example regarding the teaching of STEAMs.

Lü – Interactive Playground | 2017

Interactive projection mapping systems combined with motion capture are certainly not new in the education sector. Despite this, the Lü – Interactive Playground project has two important structural features: on the one hand, the possibility of adapting the technological

8 https://youtu.be/TqRu–oGFMy6I
9 www.immersiveclassroom.one
10 https://youtu.be/TCD3H70oSB8
11 www.play–lu.com
configuration according to the needs of the space in which it will be installed, and on the other, to offer a very wide platform of activities that allows educators and children to always make new experiences. Through the combination of projectors, XBox Kinect, and sound and light systems, Lü allows to increase the canonical environments of the school – like a gym – without altering the physical–spatial structure. Depending on the configuration chosen, it is possible to obtain more or less immersive environments in which children can play interacting tangibly with the contents projected on the walls. It is possible – for example – to play an off–scale version of space invaders by using a ball as a weapon to destroy spaceships. The goal of the project is to create new pedagogical forms, looking for a fruitful relationship between mind – body – emotions.

4. Conclusion

What has been described is intended to be an attempt to reconstruct a conceptual framework and a preliminary state of the art regarding the design of digital supports for the implementation of contemporary pedagogy. In particular, it emerges how much Design – can be an interpreter of contemporary processes and a "designer" of languages, able to adapt the interaction to the new pedagogical needs that characterize "society 4.0" in terms of critical, analytical and coding skills. The cases described, show that it is necessary, and it is possible, to bridge the gap between physical and virtual fruition, leveraging the elements of storytelling, involvement, interaction and experience, in order to develop fundamental skills in people – such as Critical Thinking (Poce & Re, 2019) – in educational context.

It is deduced that the big question is how to generate awareness and knowledge – with all the appropriate afferents – in the new generations through new educational approaches that integrate physical spaces with virtual interactions, educating – correctly – to a new way of conceiving the complexity of reality.

One possible strategy is to make a transposition from the video–gaming world to the educational ones through the application of gamification principles (Tayara & Yilmaz, 2020). These principles – leveraging the conceptual aspects of the game – allow to generate involvement and interest in a given theme, through narratives, the use of achievements, rewards and immersed environments. At the same time, they stimulate the so–called skills of the 21st century: Critical Thinking, Creativity, Communication and Collaboration (Qian & Clark, 2016)

The touch points between tangible and intangible – as seen in the examples shown – confirm that the interface is not really tending to disappear – as stated by Norman (1990) – how much it has managed – breaking the screen – to break the so–called "fourth wall"
Interface takes command. Educational environments, tools and practices to face the new normal (Caccamo, Mariani, 2020) of its theatricality, opening to a new era of interaction that involves all the senses and the surrounding space thanks to technologies.

The cultural sector – schools, museums, theatres, cultural centres – had to face the question of remote or hybrid fruition both for economic reasons and mainly because of the role of Culture as an integral and fundamental part of people's lives; as never seen before – due to the Covid–19 pandemic – Culture had to convert and adapt its way to communicate and mediate information to a new reality (Shaker, 2020).

So, If – therefore – reality and virtuality can coexist thanks to the development of digital technologies, design the education of the new normal will mean designing interfaces: tangible, multimodal, widespread–accessible and narrative (Caccamo, Mariani, 2020).

References


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Intelligent Voice Assistants: A Review of User Experience Issues and Design Challenges.

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Abstract | In recent years, voice interfaces have become the primary interaction modality with virtual assistants. While such interfaces have been advertised as a natural way to communicate with virtual agents, research has highlighted a number of issues related to voice-based interactions. Despite the abundance of commercial voice assistants, the groundwork concerning how they should be designed is still missing. Therefore, the need emerges to face the specific challenges of this novel interaction paradigm. As a contribution to the debate, a literature review on domestic voice assistants has been performed. The review follows a framework structured around three lenses: theoretical discourse, user experience, ethical issues and concerns. As a result, six design challenges have been identified. Such challenges represent spaces where design can intervene to improve voice assistants and to mitigate some of the issues stemming from their current design.

KEYWORDS | VOICE-BASED INTERACTION, INTELLIGENT VOICE ASSISTANTS, USER EXPERIENCE, ETHICS, DESIGN CHALLENGES
1. Introduction

Research on Artificial Intelligence traces its roots back to the 1950s. Machines that can interact with humans via “natural language” have a considerable heritage in both fiction (e.g. HAL 9000 from 2001: A Space Odyssey, KITT from the Knight Rider series, and JARVIS from Iron Man comics) and research. However, only in recent years have voice-based user interfaces matured enough to be embedded into many devices we interact with daily, from smartphones to televisions to cars.

More recently, voice has become the primary interface for standalone screenless devices such as Amazon Echo and Google Home. Typically, such devices are described as systems embedding virtual assistants that answer users’ questions, connect to and control multiple applications. These voice-activated devices, also called Intelligent Voice Assistants (IVAs), are making smart homes popular across millions of households in the US, Europe and Asia (Lima et al., 2019).

1.1 Intelligent Voice Assistants

Intelligent Voice Assistants (IVAs) - also referred to as Intelligent Personal Assistant, Virtual Personal Assistants, Personal Digital Assistants, Voice-Enabled Assistants or Voice Activated Personal Assistants - to name a few, support conversational interactions, most often with limited visual feedback. Placed in the home environment, they are designed to be “always-on” and “always listening”, although they engage in interactions only when prompted by users through specific keywords or sentences (e.g. “Hey Google”). From a technical viewpoint, they combine speech recognition, natural language understanding, dialogue management, language generation and speech synthesis to understand and respond to users’ requests. In general, IVAs process a wide variety of verbal instructions to, e.g., run Internet searches, access information and multimedia contents, or compose text messages.

Voice interfaces have been advertised as a natural way to interact with virtual assistants. However, several interaction problems with this type of interface have emerged, as discussed in both academic research and public debates, especially online. According to Murad and Munteanu (2019), while affordable commercial voice-based devices abound, the high-level groundwork concerning how they should be designed is still missing. As a result, there is a lack of specific design principles and usability heuristics for IVAs. Therefore, the need emerges to face the specific challenges of this new interaction paradigm, and to adapt existing heuristics and design guidelines to such emerging field.
2. A review of Voice Assistants

As a contribution to the current debate on IVAs, we have performed a literature review on domestic voice-based assistants, using a specific set of keywords to search the ACM Digital Library. As a result, a final selection of 40 papers and journal articles, all published in the last five years, have been analysed. The review was structured around a framework composed of three lenses.

The first lens examines the theoretical discourse around voice assistants: how they are designed and advertised, their potential benefits, what users expect from them. The second lens scrutinises the user experience of voice assistants. Through it, we have collected and organised outcomes from the growing research that analyses the interaction between users and IVAs in practice. The third lens covers emerging issues related to the use of voice assistants: from usability problems, up to social and ethical concerns. From this analysis, six challenges have emerged in relation to the design of such systems. They are discussed in the final section of the paper.

2.1 First Lens: Theoretical Discourse

In this section, we have summarized contributions by three influential groups of stakeholders (Krippendorff, 2005) of voice assistants: companies who design and manufacture them, users who buy them, and researchers who study them - mainly HCI scholars. Each group provides a specific point of view on the (expected) features and (potential) benefits of voice assistants, which also affects the intentions and expectations of the other two groups.

Manufacturers’ intentions

IVAs interfaces are modelled after the human-human conversation metaphor (Branham et al., 2019). By analysing users’ reviews, Purington et al. (2017) conclude that personification of the voice assistant is a marker for satisfaction. Therefore, it is not surprising that companies try to increase the probability that users personify their virtual assistants. In order to achieve this goal, and to make the conversation feel human, IVAs need to showcase unique personalities while interacting with users. To design these systems, designers define a persona (i.e. the personality and profile of the virtual assistant) and then outline the talking style, voice tone, and detailed scripts accordingly. Designers also define the details of a possible interaction, foresee the actions and reactions of the users, and design the reactions of the virtual assistant according to the situation (Lee et al., 2017).

As stated by Branham et al. (2019), who reviewed the design guidelines by five top manufacturers, voice assistants are also designed to carry on personal and efficient conversations. In order to maintain the conversation personal, the guidelines suggest the use of contextual data to cooperate with the individual. This includes remembering past conversations, especially if there is “static information and frequent actions” that will likely
For the sake of efficiency, voice assistants are designed to keep the conversation short in length and low in complexity, to avoid cognitive overloads on the user’s side.

**Users’ expectations**

The ability of IVAs to manage dialogues in a “natural” manner (i.e. fluid, simple, effortless) is at the heart of the promotional discourse surrounding them. Therefore, one of the most spread (and mismatched) users’ expectations when buying a voice assistant is that there would be no need for them to learn how to interact with it. Users expect the conversation to unfold naturally, as it happens in a regular human-human conversation. They do not expect the assistant to behave inconsistently, although that is often the case.

As maintained by Kocielnik et al. (2019), users’ expectations on AI-powered solutions tend to be inflated; however, there has been little work on designing methods for setting more appropriate expectations. This mismatch between users’ expectations and IVAs actual performance carries the risk to decrease users’ satisfaction.

**Researchers’ insights**

According to studies performed on IVAs, the possibility to enable hands-free interactions is one of the most important benefits of speech recognition technologies, due to different reasons. Hands-free interactions allow users to use the system even when they have their hands and eyes engaged in a primary activity. Moreover, voice inputs enable users who cannot write to access digital contents and to collect information from the Internet. This could impact large numbers of potential users, such as pre-school children and illiterate people. According to Lima et al. (2019), the rapid diffusion of voice control systems will particularly impact countries where a large part of the population is functionally illiterate.

Finally, some categories of elderly people or people with disabilities, in particular mobility or dexterity impairments, can be empowered by voice-based interactions (although people with speech disorders might be excluded). Despite this potential, as claimed by Branham et al. (2019), voice assistants are currently being designed with white, well-educated, young or middle-aged, able-bodied users in mind.

2.2 Second Lens: User Experience

The spread of voice assistants in millions of households raises several questions about the kind of experience users have while interacting with them. What is the nature of people’s interactions with these assistants? What kind of relationship do users’ have with them? Are users’ expectations met, and how?

Through our second lens, we reviewed studies exploring these questions, to gain a better understanding of the actual user experience with voice assistants. We focused our analysis on two main aspects: the personification of these systems and what it entails in terms of user experience; how voice assistants match (or mismatch) users’ expectations.
The Personification of Voice Assistants

Voice assistants’ ability to talk can lead users to personify them, although studies diverge in their assessment of how pervasive this practice is (Branham et al., 2019).

Lopatovska and Williams (2018) performed a small qualitative study on users’ tendency to personify Alexa. Their results show that less than half of participants engaged in personifying behaviours with this IVA, and such behaviours could mainly be explained as “overlearned social mindless responses”. In other words, users automatically responded to human-like expressions and language, without engaging in actual, meaningful personification.

The study conducted by Pradhan et al. (2019) on elderly people living alone suggests that someone who is in need of social interactions may be more likely to personify a technology, and, at times, seek social connections through it.

Porcheron et al. (2018) performed a qualitative study on the everyday social practices of households interacting with Amazon Echo. The study sheds light on the complexity of users’ relationships with such systems. Indeed, Echo is “recruited” and engaged in the intricate communications and actions, which are at the basis of the family everyday life. In this respect, the researchers observed that the use of Echo is embedded in the social order that the family members produce and live upon.

Users’ Expectations Mismatch

Recent studies conducted in household settings have highlighted how IVAs can generate the illusion of natural conversations. In this respect, human-like traits attributed to IVAs play a dual and contradictory role. On the one hand, they engage users in interactions. On the other hand, they cause users to overestimate the assistants’ intelligence, creating false expectations about their performance (Cambre, Kulkarni, 2019). In this regard, the most common technical challenge for voice assistants is speech recognition. In a study performed by Cowan et al. (2017) on a group of 20 Siri infrequent users, several problems with users’ accents and language comprehension emerged. Participants in the study provided many examples of how Siri did not accurately understand what they said.

Velkovska and Zouinar (2019) highlight issues connected to the use of indexical terms by users when interacting with their voice assistant. Indexical terms refer to contextual elements (such as “here” or “it”) that voice assistants are often incapable of understanding. In the same vein, Lee et al. (2017) mention that voice assistants receive not only simple commands from the user, but also several emotional inputs including rough and aggressive tones. Voice assistants’ inability to understand the context and the user’s emotional state is considered one of the biggest challenges for these systems, because it can undermine the quality of the user experience.

Participants also mentioned several strategies they used to prevent speech recognition mistakes, such as avoiding idiomatic expressions and speaking very slowly.
Branham et al. (2019) affirm that voice assistants, which are optimised to comprehend young adult and middle-aged voices, can have interaction problems with non-standard users’ categories (e.g. elderly people and children). Moreover, for users with cognitive impairments, the average duration of the conversation is problematic: researchers who studied populations with speech impairments, e.g. Alzheimer’s disease, and intellectual disabilities, have shown that the current timeout period of IVAs is insufficient for these users to utter their voice command. Users with visual impairments also found the timeout frustrating, but for a different reason: it limits their ability to input longer and more complex voice commands, which they are more used to adopt in human-human interactions.

2.3 Third Lens: Ethical Issues and Concerns

The spread of IVAs raises a variety of social and ethical concerns. In this section, we elaborate upon these aspects.

Reinforcement of Gender and Cultural Biases

The sound of voice conveys a diversity of cues that humans are naturally predisposed to recognize. They include the speaker’s gender, age, and personality (Cambre and Kulkarni, 2019). The use of female voices in IVAs raises controversy over gender discrimination and stereotype reinforcement. As maintained by Søndergaard and Hansen (2018), voice assistants give shape to the dominant narrative of “female servants and secretaries that are part of our collective imaginings” (p. 878). In addition to using words that can be ascribed to women, Alexa also reproduces expressions that can be associated with people with a low social status (Habler et al., 2019). When voice assistants are designed with gender stereotypes in mind, such stereotypes will be reflected in the assistant’s “personality”. As a result, pre-existing biases and stereotypes of people interacting with the assistant will be reinforced and amplified.

IVAs can also carry cultural biases. Lima et al. (2019) conducted an experiment aimed at understanding whether the user’s gender and accent influence the quality of the interaction with the system. Results suggest that accent and mispronunciation due to regional and socio-economic differences significantly affect the quality of speech recognition.

Consequences on Human-Human Interactions

Can the interactions that users have with digital artifacts affect the way users interact with other human beings? This social issue is raised by Habler et al. (2019), who investigates the effects of gendered voices and language on the perception of voice assistants like Siri, Alexa, Cortana, and Google Assistant. Results show that virtual assistants with low status language were associated with higher performance and received higher ratings by participants, as such IVAs apparently better conveyed the metaphor of obliging assistants.

Lovato and Piper (2015) raised the issue of how question-asking behaviour in children can be influenced by the use of this technology. If children begin to see IVAs as potential sources of answers to their questions, how would that affect the relationship between children and
Intelligent Voice Assistants: A Review of User Experience Issues and Design Challenges

their parents? Moreover, the authors argue that there is the risk that children “establish a master-servant relationship with robots that could bring about negative developmental outcome”, based on the results of previous studies on children-robots interactions.

Privacy

The rapid spread of virtual assistants raises social and ethical concerns also in terms of privacy and security. Firstly, IVAs are designed to be “always-on” and “always-listening”, posing serious privacy concerns. Moreover, Mitev et al. (2019) report on recent multiple attacks - consisting of unauthorized commands - against devices that utilise voice-based UIs. To check the level of security of Alexa, the scholars designed and implemented an attack to Echo’s smart lock and home security system. Their experiment demonstrates that it is possible to bypass the security features of the system by implementing malicious “skills” (i.e. software extensions that can be developed by third parties to, e.g., control household appliances or call delivery services).

Technology Anthropomorphism

Serious ethical concerns arise when technology imitates human-human conversation – the human voice in particular – to such an extent that users are driven to wonder whether they are interacting with a real person or a machine. In this regard, Google recently introduced a speech synthesis engine and dialogue system able to book appointments over the phone in place of the user. The system was so human like that Google had to add a feature to let the person at the other end know they were talking to an artificial system (Aylett et al., 2019).

At a social level, anthropomorphism of technology can have both a positive and negative impact. Positive aspects include therapeutic benefits for certain user groups. Negative consequences refer to reduced human-human interactions and the danger of manipulation. For instance, users who tend to personify their voice assistants might be more likely to share personal information with them (Pradhan et al., 2019).

3. Six Design Challenges

Based on the features of IVAs and the issues emerged in our literature review, a number of design challenges have been identified. Hereafter, we illustrate six of them, which, based on our analysis, are the most significant ones. In our view, these six challenges represent spaces where design can intervene to improve IVAs and to mitigate some of the issues connected to their use.

1st Challenge: Questioning the Human-Human Conversation Metaphor

As identified in our second lens, voice assistants’ responses do not necessarily follow the human input in a coherent way, making the interaction substantially different from the human-human one. This mismatch between users’ expectations and system performance
may affect people’s experience and their level of satisfaction (Cowan et al., 2017). This is the reason why Porcheron et al. (2018) reject the idea, popularized by the dominant promotional discourse, that voice assistants are “conversational” in nature and that the interaction with them is a “true” conversation.

Drawing on prior work about the needs of people with visual impairments, also Branham et al. (2019) critically assess the taken-for-granted human-human conversation metaphor, arguing that it restricts usage from a variety of user categories, including people suffering from blindness. The researchers solicit more inclusive interaction models, especially with respect to elements such as conversation length, complexity, and speed. According to them, not only people with visual impairments, but also other groups of users with disabilities would benefit from IVAs that adopt such an inclusive approach.

It follows that developers should consider carefully whether humanness is the right metaphor to adopt when designing a voice assistant.

2nd Challenge: Designing for Situated Interaction

The interaction between the user and the voice assistant unfolds in a specific context of use, which implies a specific set of cultural values. This cultural milieu influences the user experience and therefore needs to be considered when designing voice assistants.

According to the analysis performed by Velkovska and Zouinar (2018), the inability of IVAs to be context-aware is one of the main usability issues currently faced by developers. To improve conversational technologies, two areas of interventions are addressed. The first consists in allowing users to understand the source of the problem both when the system gives a wrong answer and when the system is unable to respond. The second consists in helping users formulate their commands effectively.

Linguistic factors also play an important role in the user’s perception and expectations. For example, research has shown that people prefer devices that use an informal language, and that preferences on gender and personality vary depending on geographical regions and languages (Cambre and Kulkarni, 2019). It is in these elements that the complexity of designing voices for smart devices across cultural contexts lies.

“For example, the word for “dishwasher” is masculine in Spanish, yet feminine in German. Would these linguistic cues make it more likely for a Spanish speaker to expect a male voice from a smart dishwasher, and more likely for a German speaker to expect a female voice from the same smart dishwasher?” (Cambre and Kulkarni 2019, p.10).

The authors conclude that there is no globally optimal voice for a certain device that obtains users’ liking across different cultures.
3rd Challenge: Aligning Users’ Expectations and System Behaviours

It is well recognized that the user experience of a system cannot be evaluated considering only performance or usability (Gürkök et al., 2011). Indeed, such evaluation is highly influenced by prior user expectations as well as by the specific context of use. The findings of a study performed by Kocielnik et al. (2019) show that shaping users’ expectations correctly can be an effective way to improve user’s acceptance of AI-based solutions.

The alignment of users’ expectations with the actual system behaviour is the focus of a study by Azmandian et al. (2019). Based on their results, the authors acknowledge that designing the behaviour of virtual assistants is a challenging problem: the alignment of end users’ expectations with an agent’s actual behaviour is indeed influenced by many factors. What makes it harder for designers to address the issue is that, in any specific interaction, there may be more than one correct answer regarding how an agent should behave. Indeed, even if designers purposefully create personas to attain a desired user experience, the same persona will be perceived differently by different users. This is the concept of second-order understanding, well-illustrated by Krippendorff in his semantic turn (2005). Therefore, designers should include the perspectives of end users in the persona-creation stage, gathering viewpoints related to what different user groups or individuals might expect from their voice assistants (Pradhan et al., 2019).

4th Challenge: Is Voice just Voice?

Cambre and Kulkarni (2019) investigate how users would react if the IVAs’ voice were gender neutral. Some researchers have already proposed gender-neutral voices for voice interfaces. We might also question the choice of replicating a human voice in virtual assistants, instead of having a deliberately robotic type of voice. Non-human voices may indeed mitigate some of the issues related to the mismatch of users’ expectations and to the reinforcement of cultural biases and gender stereotypes.

According to Kim et al. (2018) the single-medium, voice-based communication limits expressiveness and richness of information. In their view, IVAs designers should explore multimodal interaction modalities. They propose, for instance, adopting tactile forms of interaction to enrich people's experiences with IVAs.

5th Challenge: Designing for Embodied Interactions

To date, designers and researchers have largely focused on the conversational aspects of voice assistants. What has been neglected is the form and embodiment of this technology, as well as how that makes a difference in the user experience. Cambre and Kulkarni (2019) believe that, besides the specific context of use and the characteristics of the voice interface, the user experience is also “shaped” by the physical dimension of the devices. Therefore, form, aesthetics, and physical features do influence the resulting experience of users.
According to them, adopting a human-robot interaction (HRI) perspective would offer a more holistic approach, since HRI merges embodiment and voice in its research.

6th Challenge: Taking a Political Stance

As maintained by Søndergaard and Hansen (2018), voice assistants are neither innocent nor neutral: regardless the actual awareness of their developers, they are political entities that raise ethical and philosophical issues. Such issues should be addressed and acknowledged by all the stakeholders we analysed in our first lens (manufacturers, users, and researchers) but above all by researchers and designers. Aylett et al. (2019) claim that the mere analysis of the systems in place – as most researchers have been doing – is not going to innovate IVAs. Researchers and designers should take an active role in questioning the status quo, also by developing provocative and critical artefacts that challenge the dominant perspective on the design of IVAs. A recent example in this direction is VORO, a couple of “data hungry pets” that perform their role as smart assistants correctly only if the user gives them attention and constantly feeds them with the data they crave. According to its designer Findlay Macdonald, VORO is meant to challenge “the current paradigm of the lack of control that we, as users of smart home products, have over our data.” (https://www.finmacstudios.com/voro)

In a similar vein, instead of reproducing traditional gender roles, IVAs could be designed to question them and to leave them open. If the design community does not take up these challenges, large corporations will continue to set the rules, pursuing their commercial objectives. As a result, any possible alternative scenarios - built upon a different conception of humanness, culture, and interaction modalities - will have no chances to come into being.

4. Conclusions

We performed a literature review aimed at providing a structured overview of scholars’ contributions in the field of IVAs, organized around a three-lens framework. We also outlined six design challenges, which represent a call for the design community at large to take action, both by developing consistent design guidelines, and by envisioning and prototyping novel and critical alternatives for IVAs.

As Søndergaard and Hansen (2018) point out, technological futures are built on and (re)produce collective imaginaries that intersect technology with social, cultural, and political matters of gender, race, and class. Such technological futures, therefore, are not pre-determined, although not entirely open either. Indeed, it is the designer’s task to challenge the dominant narratives in order to propose different, and still acceptable, futures.
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Research on Gender Differences of Adult Head Shape in China

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Abstract | Studying the differences in head shape, especially between genders, is vital to the design of head-mounted products. However, current studies on the head size of contemporary Chinese remain incomplete. Therefore, this study collects the latest head-related data from 2200 male and female adults from typical cities in seven populous areas of China, and analyzes gender differences in the head, face, eyes, nose and ears according to the items measured. Specifically, feature data collected through 3D measurement include averages, standard values, maximums, minimums and percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles). The results show that in the analysis of 33 features of 5 categories, the averages of male adults are larger than that of female adults (p<0.05). Additionally, the head models of male and female adults in China generated from the above mentioned data provide the design of head-mounted products with data support and references about gender differences.

KEYWORDS | HEAD-PRODUCT DESIGN; ANTHROPOMETRY; ERGONOMICS; 3D SCAN; CHINESE HEAD AND FACE
1. Introduction

With the rapid growth of smart wearable devices, more and more head-mounted products come out. A head-mounted product needs precise data about head features to achieve high suitability (Ball, et al, 2008). Therefore, studying the differences in head features is vital to the design of a head-mounted product. In the past, the head was measured with contact measurement tools like tape and caliper to collect head length, width and circumference (Huston, 1995). For traditional head-mounted products like hat or bicycle helmet, this type of product differs in their “suitability” to men and women largely because of their differences in size with head breadth, head length and head circumference as the basis of data. Yet, as more smart head-mounted products emerge, e.g. VR and AR helmets, cephalic and facial parts involved become more complex and diverse, and since head curves are diverse and divided into elastic part and inelastic part, traditional contact measurement mode is unable to satisfy deeper study needs (Widyanti, 2015). In this case, the development of 3D scanning techniques can make up for this problem.

As 3D scanning technique advances, currently there is a growing number of studies about 3D measurement, especially for head and face: in Europe and America, L. Talbert et al. (2014) conducted a study of 3D analysis of facial features of white Americans and African Americans, while Perret-Ellena T et al. (2015) conducted 3D anthropological measurement of head and face of children in Holland to better design oxygen masks for them; Zhuang et al. (2005) used an advanced 3D scanner to capture the facial features and corresponding changes of American respirator users.

However, the current studies on the head size of contemporary Chinese conducted at home and abroad are not thorough: in 2008, SizeChina completed by Roger Ball is the first digital database to store head and face shapes of the Chinese people, yet it has some problems, including outdated samples, limited facial and aural features extracted in number and poor data precision; in 2016, the China National Institute of Standardization (CNIS) used 3D scanning technique to set up a regression model of body size with male adults as samples measured (Xing, 2017). As a result of the lack of analyses on head differences among Chinese, most of the head-mounted product designers who target users are Chinese relied on Western anthropometric data, making it hard to produce head-mounted products more suitable to the head of Chinese.

Through 3D scanning and measurement of the head of the respondents, this study set up a digital model, thus acquiring massive data about the heads of Chinese adults. Besides a traditional analysis of the sizes of men and women (averages, standard values, maximums, minimums and percentiles), methods like feature point fitting were also used to analyze data about male and female heads and output a visual model. The purpose of this study is to set up a Chinese head measurement data system that is more complete and accurate and identify the relationship between gender and different head-related parameters, to enable it to be applied more effectively in the field of head-mounted product design.
2. Sample distribution and data collection

2.1 Sample distribution

This study selected 2200 adults from typical cities in the seven populous areas of China, and the numbers of male and female respondents recruited in each region are basically the same. Advanced non-contact optical scanning technique was used to obtain high-precision data on head shape, then 3D data was processed to get 3D model files, 57 features related to head, face and ears were extracted and 33 related items were measured (Fig.1).

Figure 1. Sample size and sample distribution.

2.2 Features measured

33 anthropometric and anatomical characteristic points (Fig.2) defined in this measurement and study are:

- Head circumference (HC): The maximum circumference of the head just above the ridges of the eyebrows (supraorbital ridges) and the attachment of the ears;
- Head length (HL): The distance from the glabella landmark between the brow ridges to the rear-most (posterior) point on the back of the head;
- Head breadth (HB): The maximum horizontal breadth of the head above the attachment of the ears;
- Frontotemporale Distance (FD): the minimum frontal width, which is the horizontal distance between left and right frontotemporale;
- Glabella - Pronasale Distance (GPD): The vertical height of the nose, which is the vertical distance between glabella and pronasale;
- Infraorbitale - Pronasale Distance (IPD): The vertical distance between infraorbitale and pronasale;
- Tragion distance (TD): The horizontal distance between left and right tragion;
- Zygofrontale Distance (ZD): The horizontal distance between left and right zygofrontale;
- Otobasion Superius Distance (OSD): The horizontal distance between left and right otobasion superius;
- Glabella – Otobasion Superius Distance (GOSD): The projection length on the sagittal plane of the straight line between glabella and otobasion superius;
- Vertex - Glabella Distance (VGD): The vertical distance between vertex and Glabella;
- Vertex - Tragion Distance (VTD): The vertical distance between Vertex and Tragion;
- Infraorbitale Distance (ID): The horizontal distance between left and right infraorbitale;
- Glabella-Infraorbitale Distance (GID): The vertical distance between glabella and infraorbitale;
- Biocular Distance (BD): The horizontal distance between left and right Ectocanthus;
- Interocular Distance (ID): The horizontal distance between left and right Entocanthion;
- Interpupillary Distance (IND) : The distance between left and right pupil;
- Otobasion Superius - Pupil Distance (OSPD): The projection length on the sagittal plane of the straight line between pupil and otobasion superius;
- Sellion – Pronasale (SP): The vertical distance between sellion and pronasale;
- Sellion – Subnasale (SS): The vertical distance between sellion and subnasale;
- Pronasale - Subnasale Distance (PSD): The straight-line distance between pronasale and subnasale;
- Alare Distance (AD): The horizontal distance between left and right alare;
- Otobasion superius - otobasion inferius Distance (OSOID): The vertical distance between otobasion superius and otobasion inferius;
- Ear Length (EL): The distance between superior auricle and inferior auricle;
- Ear Breadth (EB): The distance between posterior auricle and otobasion superius;
- Cavum Concha Length (CCL): The distance between superior cavum concha and incisura intertragica in the direction of the ear length;
- Cavum Concha Width (CCW): The distance between posterior concha and tragion in the direction of the ear breadth;
Superior Cavum Concha to Anterior Cymba Concha Length (SCCACCL): The distance between anterior cymba concha and superior cavum concha in the direction of the ear length.

Figure 2. Characteristic points.

2.3 3D data collecting and processing

The measurement group of this study consists of many well-trained anthropometers and professional photographers. This group finished collecting data on head from typical cities in the seven areas in mainland China within four months. Since the number of the members in the measurement group is limited, the research group would hire around 5 staff locally for assistance in each place. In the whole process, the measurement group would spend around 2 days checking and adjusting the venue and installing and calibrating devices, and the scanning process takes 2 to 3 days. Therefore, each measurement point needs 4-5 days to finish collecting expected data. The concrete data collecting process takes the following steps:

1. Project introduction and questionnaire filling
2. Numeration and photographing
3. Traditional anthropometric measurement
4. Fixing hair
5. Feature point marking
6. 3D scanning and data check

2200 original datasets collected through scanning need to be preprocessed before extracting feature-related data and measuring and analyzing related features. This process includes the following steps of data processing (Fig.3):

1. Data alignment
2. Noise elimination and integrated registration
3. Sharp fusion
4. Mesh simplification and hole filling
5. Mesh smoothing
6. Texture mapping
7. Uniform coordinate system
8. 3D file export

Figure 3. 3D Chinese head model.

3. Sample data analysis

The features measured in this study are divided into five categories, namely head, face, eyes, nose and ears, and each category is subject to data statistics and comparison by gender. Statistical data about 3D measured features include averages, standard deviations, maximums, minimums and percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles). Anthropometric data of this study used IBM SPSS Statistics 23.0 software package (IBM, US) for analysis and summary. Two-factor analysis of variance (ANOVA) was adopted to identify the influence of gender on human body characteristics of the head, Tukey’s honest significant difference (Tukey HSD) was used for ex post analysis and multiple comparisons. When Sig. value (p) < 0.05, it is believed that it is of statistical significance. Pearson correlation coefficient (r) was used to conduct a bivariate correlation analysis and examine the correlation between dependent and independent variables. The results show that in the analysis of 33 features about head, face, eyes, nose and ears, the averages of 33 features measured of men are all larger than that of women (p < 0.05).
3.1 Comparative analysis of head features

Tab.1 shows detailed statistical data on head circumference, head length and head width by gender. Among three measured features, the average head circumference, head length and head width of men are greater than that of women (p<0.01). Besides, the head circumference, head length and head width of men at every percentile (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles) are larger than that of female heads at the corresponding percentiles.

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3.2 Comparative analysis of facial features

Tab.2 shows detailed statistics about frontotemporale distance, glabella-nasal tip distance, infraorbital point-nasal tip distance, tragion distance, bizygomatic breadth, supra-auricular point distance, supra-auricular point-glabella distance, vertex-glabella distance, trichion-tragion distance of different gender groups. According to the analysis of facial features, the averages of the nine features of men are all larger than that of women (p<0.01). Meanwhile, all the measured features of men are larger than that of female heads at every percentile (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles).

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3.3 Comparative analysis of eye features

Tab.3 provides detailed statistics related to infraorbital point distance, glabella-infraorbital point distance, outer canthus distance, inner canthal distance, inter-pupillary distance, supra-auricular point-inter-pupillary distance of the gender groups. Among eye-related items measured, the averages of the six features of men are all larger than women’s (p<0.05). Moreover, all of the measured features of men at every percentile (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles) are larger than the same features of women at the corresponding percentiles.

3.4 Comparative analysis of nose features

Tab.4 offers statistics of nose bridge-nasal tip distance, nose bridge-subnasal point distance, nasal tip-subnasal point distance and interalar distance of the groups by gender. The averages of the four features among nose-related features measured of men are all larger than that of women (p<0.01). In addition, measured features of men at every percentile (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles) are all larger than corresponding female characteristics.

3.5 Comparative analysis of ear features

Tab.5 shows ear-related features measured, among nine features of men, the averages of their superaurale-subnasale distance, ear width(left/right Y), right ear length (left/right X), postaurale-preaurale distance (left/right Y), preaurale-superaurale distance (left/right X) are
larger than women’s (p<0.01). Meanwhile, measured features of men at each percentile (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles) are larger than that of women at the same percentiles.

4. Correlation coefficient

According to physiological characteristics of the human body, the indexes of all the body parts are not completely independent, as all the characteristic parameters are highly correlated (Li, 2013). This study conducted a correlation analysis of 33 items measured, Pearson correlation coefficient can effectively calculate the correlation between different characteristics: 0.8—1.0 is highly strong correlation; 0.6—0.8 is strong correlation; 0.4—0.6 is moderate correlation; 0.2—0.4 is weak correlation; 0.0—0.2 is highly weak correlation or non-correlation. This article highlights 18 features whose correlation is between 0.6 to 1.0. The results are shown in Fig.4.
5. 3D head model fitting

To further estimate sexual dimorphism, this research utilized a new facial framework analysis: a Frankfurt plane (Borman, et al., 1998) was used as a XOY plane to establish a dimensional coordinate system where the x-axis signifies nose tip, y-axis signifies tragion and z-axis signifies head vertex. The XYZ coordinates of 33 facial feature points were extracted. Then, the P-th percentile of XYZ coordinates of each feature point was calculated, and their spatial positioning was determined using the 3D software. Features were finally connected to establish the facial framework (Dong, et al., 2011) of the P-th percentile. 3D facial frameworks of different percentiles for both genders were established using the above method. Gender-wise models of the same percentile were superposed, and the absolute differences of features indicate facial size differences between Chinese male and female adults. Additionally, comparative differences in different percentile models for each gender are also of reference value as single-gender feature data.

Based on early-stage data, this research employed a fitting method of layer-by-layer circular scanning to divide human face into 4 feature regions; after that, layer-by-layer circular scanning sampling and contour sampling were conducted, followed by calculation of distance and layer percentiles and construction of curved surface of head using the point sets comprised of point coordinates exported from the software; finally, male and female head models ranging from the 5th through 95th percentiles were fitted. Diversified head statistical models are significant as they provide designers with more effective data and anthropometric features, which play a positive role in advancing the development and manufacturing of new wearable products targeting Chinese users (Fig.5).
Conclusion

Wearable products represented by VR headsets entail a high requirement on adaptability, and products failing to perfectly fit to users’ face often have problems like concentrated pressure, light leak and slippage. The standard Chinese male and female 3D head models and anthropometric measurement data obtained in this research can be used to test wearable products in a virtual CAD environment using simulation methods, and thus are of guiding significance for designing and developing headsets adaptable to different features of male and female.

References


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Speculative Physical Models Created Through a Robotic Process.

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Abstract | New opportunities exist to imagine the architectural model in a digital era. Rather than view the physical and digital as oppositional, both model types possess qualities of operation, performance, and mediation. This paper discusses the speculative physical model as the driving motivation for a three-credit elective seminar: Introduction to Robotic Fabrication. The undergraduate/graduate course did so with students without any previous robotic exposure. Speculative architectural models confront material, production, sequence, and gravity. Models are surrogates, as all forms of design must confront translating ideas to reality. Typically, designers specify, while others build those designs. Designers’ models translate issues of scale and production. The course operates in opposition to digital fabrication courses where furniture-scale prototypes result. Speculative scale-models utilized the robot as a mediator in a speculative construction process. By building models, students understood their work to be at a large-scale, which would then require robots to be construction tools.

KEYWORDS | ROBOTICS, DIGITAL FABRICATION, SCALE-MODELS, HIGHER EDUCATION, FOURTH INDUSTRIAL REVOLUTION
1. Introduction: cultural background

Contemporary design takes place within the framework of a global change that simultaneously affects the manufacturing, education, and research sectors known as the Fourth Industrial Revolution (Schwab, 2017). The Fourth Industrial Revolution is based on the spread of cyber-physical machines/systems interconnected through the internet of things that allow the automation of the tasks necessary to carry out complex processes. In other words, this technological era is represented by the diffusion of production tools that impact the professional skills needed to govern them.

The computer, democratized as part of the digital revolution, is not only a design tool but a mediator that translates digital models into programming languages readable by 3D printers, numerical control machines, laser cutters, and robots (Picon, 2010). The consequence in architecture lies in the openness to new design languages that encourage the development of innovative construction techniques for the rapid production of technological elements, disconnected from the impositions of prefabrication.

In architecture, the compression between design and construction has been theorized by Mario Carpo as Digital Turn, which develops in two consequential phases. With the first Digital Turn, new possibilities opened up through computational thinking in design processes (Carpo, 2013). With the Second Digital Turn, more in line with the shift dictated by the Fourth Industrial Revolution, robotic proliferation leads to a synthesis of algorithmic and parametric design informed by advanced forms of making. Robots can process and cut material while also assembling discrete, heterogeneous parts. Parametric thinking allows designers to understand projects as a set of operations, and the robot can support this type of production where parameters result in accurate iterations controlled by robotic making.

The robotics course presented in this paper, which has as its output the definition of architectural scale-models, is based on the realization that the current system of higher education is conditioned by dynamics that disadvantage students’ cognitive opportunities. In the academic field, within the design workflows, the cost of making models progressively goes up, while on the contrary the cost of making digital models goes down. This trend causes students to move away from the cognitive and tactile experience of making physical models. From this, a loss of physical modeling occurs, which follows a loss of kinesthetic knowledge and rigor in the design process. The loss of physical models has already been witnessed in professional contexts. The possibilities dictated by the digital era encourage morphological explorations through 3D printing. However, 3D printing exists more as direct output biasing geometry over performance. While an essential tool, there is an inherent lack of materiality in 3D printing to date.

The realization of analog physical models has several advantages. First, the models are configured as a medium to make the process explicit and to make the understanding of the project accessible to both the student and the educator (Voulgarelis & Morkel, 2010).
Moreover, maquettes represent a graphic form defined by a material dimension where surfaces are informed by a tactile knowledge (Ingold, 2013).

The knowledge gained by making can only occur through doing. Marty Neumeier, in the book *Meta Skills, Five Talents for the Robotic Age*, articulates: "500 years after the Renaissance, academic education in the West has been successful in separating the hand from the brain. We've decided that making things is less valuable than knowing things, and therefore making has a less place in the classroom. This is not only wrong, but it denies the very evolutionary advantage of being human". Neumeier also adds that to cultivate the necessary skills in the contemporary world, "making is rejoined with knowing" (Neumeier, 2012). This is fundamental especially in the discipline of architecture, which in the Vitruvian definition results from the fusion of theory and practice. In his *Ten Books on Architecture*, Vitruvius advocates for architects to possess theoretical and practical knowledge, to combine manual skills with profound scholarship. In particular, practice is described as "the frequent and continued contemplation of the mode of executing any given work, or of the mere operation of the hands, for the conversion of the material in the best and readiest way" (Pollio, 1914).

In the construction tradition, craftspeople are those professional figures who embody the synthesis between theoretical knowledge and practical experience, manifesting the approach learning-by-doing and thinking-through-making, "rather than acquiring theoretical precepts for subsequent application in practice" (Ingold, 2013). An interpretation of the concept of learning-by-doing is inherent in the theorization of *Il Discorso Mentale*, the mental conversation, raised by Leonardo Da Vinci in reference to the creative process for the creation of works of art such as paintings: "to Leonardo, an artist didn't learn to paint. He painted to learn" (Neumeier, 2012).

Therefore, through the teaching activity, the course emphasizes making as an attitude to study material and focus attention to the detail. The course attempts to recover the sense of materiality that is lost with simple BIM models and additive rapid prototyping. The production of architectural models is a good opportunity to explore the cultural implications and the transposition of the skills of future operators of the Fourth Industrial Revolution. In contrast to the simple output afforded by 3D printing, robots operate as mediators building the students' translational skills. By exploring the robotic possibilities to make scale-models, it is possible to refine the skills of digital fabrication while exploring matter, which informs the programming of design algorithms in an iterative way.
2. Relevance of the subject: making scale-models

This course balanced theoretical and instrumental aspects through readings that introduced topics, demonstrations of software, and hands-on sessions for introducing robotic-student interactions and protocols. This approach highlighted that production is no longer solely the last step of the design process. The technical knowledge taught was used to understand the potential and operational limits of the robot - considering both the workcell and the limit angles of the axis kinematics - in order to approach the design process accordingly. In parallel, theoretical knowledge laid the foundations to open a dialogue on the speculative value of architectural models.

The concept of scale-model as machine (Smith, 2007) was introduced to explain the evocative quality of architectural models, not only as objects of study but as an expression of a deep disciplinary value system. The first example discussed was Gaudi's approach to the creation of scale-models. Although the architect worked at the end of the nineteenth century, his "reference standards" were those of the Middle Ages, a period in which making architecture was guided by the master-builder, a craftsperson who, without the need to produce drawings, directed the day-to-day construction. In the same way, Gaudi in his professional life did not make any written notation to represent his projects. For Gaudi the realization of scale-models served not only to explain to the craftspeople his complex geometric ideas, but above all to recall the moral and religious social order of the past, as an example to be pursued. Among the methods used by the architect to understand the systems of forces in the load-bearing structures, there is the process of hanging chains upside down above a mirror. In this way, he created real "machines" to explore nature and to understand the truth of invisible reality, or in other words, God.

The search for the unknown also belongs to Louis Kahn’s work. As Albert Smith explains in his book *Architectural Model as Machine*, in developing his design processes, Kahn discovered that "the scale-model machine presents not only the possibility of seeing and defining the narrative of the myth, but also seeing its failing" (Smith, 2007). It is part of this narrative to find out what the future appearance of a building will look like or how the scale-model will contribute to the advancement of design towards construction, whether by suggesting a different approach to materials or changing proportional ratios. Since in Kahn’s poetics, as in Gaudi’s, there was a profound spirituality underlying it, he saw in the order that springs from architecture, an allegory of the universe unifying all things. In both instances, the architect saw great intellectual value in the creation of physical models.

From an educational point of view, we tried to convey the fact that an architectural model is a prototype that serves to convey an idea and transform it during the design process. Like a prop in the theatrical lexicon, the scale-model is an object that serves to build a concept and make it explicit through its materialization. Students were also exposed to the idea that direct experience has cognitive benefits on learning. Just as Leonardo Da Vinci used painting as a means of knowledge, the architect can take the same path through the creation of study models. This knowledge-building activity through direct tactile experience, through the
Speculative Physical Models Created Through a Robotic Process

medium of the hand touching material, is human learning and "will proceed without respect to any prediction of normative measures of intelligence" (Wilson, 1999). Paraphrasing Frank Wilson's words in *The Hand: How Its Use Shapes the Brain, Language, and Human Culture*, the hand, through external interactions, trains the brain to understand reality. In material exploration, "both the hand and the eye develop as sense organs through practice, which means that the brain teaches itself to synthesize visual and tactile perceptions by making the hand and eye learn to work together" (Wilson, 1999).

A physical model is an important cognitive part of the design process. It represents the connection point between thought and action, between tactile experience and the brain. In this course, the robot exists as the translator between mind, digital conceptualization, and the material world. The designer's workspace extends, as does the cognitive space. The use of industrial robots and design software allows mutual communication between the parts and does not render the robot as a simple executor. Moreover, the use of robots introduces us to a new process model in which a new aesthetics is inherent, both from the point of view of the possible geometrical results and of the speculative value related to them.

3. Methodology: the digital (robo)fabrication class

A recent article, "8 Things Every School Must Do to Prepare for the 4th Industrial Revolution" published in Forbes, presents an analysis of what higher education should offer to make future professionals more responsive to the quickly evolving dynamics of the market. On the basis of future trends that will occur in the world of work,¹ it will be necessary to emphasize, alongside humanities, the STEM (science, technology, engineering, and mathematics) disciplines, as together with the critical thinking, "there's no doubt every worker in the future will need some tech skills."² A further point that is touched upon is the updating of teaching methods and themes. The rapid changes in technology make traditional models obsolete, which require a large part of learning to take place by the end of university graduation. The acquisition of skills is driven by the ability to use the tools that require more than basic knowledge or the simple ability to follow instructions. These tools, as summarized by Darrell West in *The Future of Work*, fall within the macro-categories of automation, robotics, AI, machine learning, and IoT (West, 2018). They are the key to updating higher

1 “The Future of Jobs Report 2018”, by *The World Economic Forum*. In the introduction, the executive chairman Klaus Schwab states: “a particular focus of this new edition of the report is on arriving at a better understanding of the potential of new technologies, including automation and algorithms, to create new high-quality jobs and vastly improve the job quality and productivity of the existing work of human employees.”

education through a non-static approach, so that the university education offer does not prepare for the future professionals that "we needed 50 years ago."³

By adopting this innovative approach to models, the Lawrence Technological University - College of Architecture and Design has defined the methodology for teaching an introductory course in robotic digital fabrication. The course is taught during one semester and is offered to a small group of undergrad and grad students, with no prior exposure on the topic. The students used a Kuka Kr6 six-axis industrial robot, previously deployed in an automotive production chain and then absorbed by the university, which benefited from a lower investment, instead of purchasing a new tool just released on the market. The robot was provided by Ballard International, a company that takes used robots from the automotive industry and resells them. Ballard International’s business model is to connect tools and the culture of manufacturing to multiple sectors, including schools.

The use of "retired robots", or downcycled, or used, is currently a growing trend. Teaching and academic research are part of one of the areas where it is possible to use retired robots in the post factory years, after the assembly line. The Economist's 2014 special report "Immigrants from the Future” mentions the startup company Bot and Dolly, later acquired by Google, which used industrial robots in new settings like art projects and the film industry. The robot-afterlife is a condition that is generated when manufacturing industries upgrade their production lines with more competitive and advanced instrumentation. However, robots can operate for many years after they are displaced from assembly lines, making them affordable to subsequent customers, who usually make targeted and less intensive use of them. These sectors do not have the capital purchasing power of the industries that originally purchased the robots. The reduced cost of used robots (Keramas, 1998) defines in parallel an exponential growth of technical and operational knowledge in the automation sector. In the case described in this paper, necessary expertise for the Fourth Industrial Revolution can be achieved through university education.

In the digital (robo)fabrication class, the teaching approach has been to consider the robot as a mediator to translate ideas into reality. Through robotic fabrication it is possible to transfer digital information into materiality through an instant connection between digital three-dimensional models and physical space. The course led students through a series of assignments that started with basic robotic programming, with various exercises along the way, to the culmination where the robot hotwire cut precision formwork for a series of plaster models. The flexibility allowed for the use of a single robotic process given different tools to perform additive, subtractive, hybrid, and assembly processes.

The most effective entry level mode to program a robot is to combine 3D modeling with custom made plugins to control machine operations through a digital interface. In this case,

Rhinoceros and Grasshopper have been implemented with Kuka|Prc, an add-on that converts geometry into robot-readable lines of code. The most effective workflow to program the robot kinematics consists in drawing the machine-path, or toolpath, in three-dimensional space. This, within the limits of the workcell, is the maximum extension that the robot axes can reach. The toolpath is then broken down into target points described through polar coordinates that constitute the instructions to be given to the robot, importing the file into its operating system. Different end-effectors can be installed on the robot to perform different tasks, making the robot flexible and adaptable to different functions. This functionality allows the students to increase complexity of robotic operations through iterative optimizations. The digital interface visualizes the robot and its movements to detect and correct errors before execution in the physical world. Kuka|Prc is widespread in the academic world for programming Kuka robots because of the popularity and student familiarity with Rhino. Kuka|Prc’s diffusion in academia is the result of its effectiveness of an online community active on the development of the theme, through which access to knowledge is reverberated to the non-experts.

An early assignment in the course was to produce long exposure photographs drawn with light where the robot did not touch material. To perform the exercise, students installed a LED light on the robot. Then, they took a photo in bulb mode for the duration of the kinematics (Figure 1). The result is a geometric composition through which to visualize the effects of algorithmic programming. Association was made with the themes of technological production between the exercise and the motion studies of the industrial engineers Frank Bunker Gilbreth and Lillian Evelyn Moller, who was also a psychologist. Gilbreth developed a study method to analyze the movements of workers on assembly lines in the 1910’s. By taking long exposure photos, the mechanical sequence and timing of repetitive tasks was possible, in order to intervene on their rationalization, instead of making changes to the work environment to improve the efficiency of the production process. With the same logic, students were able to rework the code and set the software deciding whether to optimize the execution time or the number of axial rotations to complete a given action. Time is therefore the fourth dimension in three-dimensional space to be taken into account in the production phase, dictated by mechanical motions.

For teaching purposes, exercises have been structured to manage the complexity of design in three-dimensional space. One of these consisted in using the robot to perform a repetitive task on a variable volume, i.e. to guide the insertion of nails at regular intervals in the normal direction to a doubly curved high density foam surface (Figures 2-3). The same exercise was implemented by requiring the robot not only to reach single target points but to draw a path with continuous lines (Figure 4). Using robotic fabrication, the concept of iteration and repetition no longer requires standardization. Students explored flexibility afforded by robots through the development of their own custom end-effectors (Figure 5). The robot held and positioned custom tools with dexterity and precision.
Once the technical foundations were laid for the course through simple and direct exercises, it was possible to approach the exploration of speculative architectural models. For this more complex work, a hot wire cutter was installed on the robot as an end-effector. The purpose of the assignment was to explore through concept tests the study of stereotomy at the scale of architectural models. Students were asked to design cutting plans to be performed on 10 by 10 by 10 cm cubes. Each cube had to be cut at least 5 times. No indication was given on the characteristics of the cutting plans, which could be single, composite, straight, or curved. Through algorithmic design, it was possible to iterate the formal generation process, change the cutting sequences, and simulate the result. Each working group produced 20 models and each iteration was informed by the model scale previously created (Figure 6). Acting directly with the hot wire on the high density foam, the students also had feedback from the material itself. Based on the result obtained, they were able to optimize the robotic programming by modifying the cutting temperature or the kinematics speed. From the volume, we moved on to the design of the production sequences, which took place without a privileged direction, from bottom to top or from outside to inside, but according to the logic of process efficiency, to confirm the quality of the result. Robotic fabrication made it possible to quickly produce repetitive or non-standard complex shapes that are difficult to produce by hand, with no limits to creativity.

Building on the previous assignment, the final project required the students to use the hot-wire cutter to produce formwork for casting a plaster model (Figure 7). Not only was there an inversion of solid and void, but the assignment added a secondary material process of casting. The students generated multiple complex models, always starting from a solid cube and working on doubly intersected voids. The models were displayed as part of a final exhibition of work (Figure 8) with human scale figures emphasizing the desire to view the work not as desktop objects but proto-architectural explorations.

The intense connectivity between design software and robotic output creates an instantaneous workflow. Designers are able to continue designing right up to the point they export robotic code for the production process. The design also goes beyond the limits of geometry and includes a schedule of new design parameters. In the context of the course, students limited themselves to the creation of speculative models, but the methodology is scalable and in so doing, it challenges traditional design approaches. Through robotic digital fabrication we can exit the drawing sheet in order to make things, not only drawings of things (Gramazio et al., 2017).

4. Conclusions

In the design and construction scenario that lies ahead, the master-builder/designer will take care of the entire production chain. This professional will be able to summarize the complexity of the workflows within The Fourth Industrial Revolution with respect to the logic that governs manufacturing processes. The master-builder will investigate issues related to
the synthesis of computation and digital fabrication as elements capable of triggering innovation to an area of study increasingly oriented towards architecture and construction, involving industrial processes and academic training.

Through this class, students had the opportunity to understand the value of upstream and downstream processes. The upstream process includes design, i.e. the early-stage phase where the morphological decisions are taken and the design strategy defined. In the future of construction, the downstream phases will be digitally connected and inevitably include tools such as robots. The downstream design process is informed by production methods, enriching the creative phase with data through the knowledge of tools that allow upstream cognitive integration. In this context, the algorithmic language is the link between the different phases of the workflow from design to construction.

In the class, a loose analogy between robots and contractors emerged and if one could explain intentions and constraints to a robot, an emerging designer must be able to describe their intentions and instructions to a contractor or manufacturer. Architects can use digital technology to better understand downstream production processes. As a result, technical complexity can be handled early in the design process to make better informed decisions and achieve better operations.

Students learned physical aspects of prototyping, with the aim of bringing digital fabrication back to a material dimension, combining architectural design and production process in a hybrid workflow. The same workspace in which the robot operates is hybrid, by continuously exchanging information between real and digital and vice versa.

The course focused on process analysis and cultural implications. Since it was an introductory course for robotic digital fabrication, students did not have to deal with design aspects such as functional program, occupancy, static operation, or placement on a project site. The work focused on the design phase, avoiding to follow the rules that professional determinism imposes. Mediating design and material was a key skill to utilize speculative models based on the new forms of digital models that define an emerging relationship between designer and tools. Students practiced working out formal concepts and thinking about the tools that were used to produce them. Borrowing the words of Louis Kahn, "form has nothing to do with circumstantial conditions" (Kahn, 2003). As a result, students were able to start building their own "reference standards" in anticipation of becoming the next professionals in architecture to embrace the Fourth Industrial Revolution, with the socio-cultural consequences that it entails.
Figure 1. The robo-lightpainting assignment within the Introduction to Digital (robo) Fabrication class at Lawrence Technological University – College of Architecture and Design. Work by students: Francisco Landeros, Zakia Hunt, Aaron Wrubel, and Michael Zonca. Instructors: Karl Daubmann and Sara Codarin.
Figures 2-3. The “pin-head” assignment. Work by students: Irene Missler, Matthew Weyhmiller, Trent James, and Eunpyeong Kim. Insertion of nails in the normal direction to a double-curved high density foam surface.
Figure 4. The flow-lines assignment. The students designed their own end-effector using digital fabrication, so that they could draw in three-dimensional space on a doubly curved surface. Work by students: Francisco Landeros, Zakia Hunt, Aaron Wrubel, and Michael Zonca.

Figure 5. The end-effectors used during the robo-class. Each of them can be installed on the robot and act as an actuator to perform customized tasks.
Figure 6. Iterative foam scale-models made by students through robotic hot wire cutting.
Figure 7. Plaster models made using foam formwork produced through robotic hot wire cutting. Work by: Eunpyeong Kim, Michael Zonca, and Irene Missler.

Figure 8. Final exhibition. Work produced by students throughout the digital (robo)fabrication class.
References


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Teaching Design in the Age of Platforms: A Framework for Platform Education

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Abstract | Our contemporary social, cultural, and political experiences are increasingly mediated and shaped by digital platforms, such as search engines, content intermediaries, and networked communications tools. A digital platform is the provider of software, sometimes hardware, and service that uses computational architecture to mediate social activities strategically. Contemporary communication design practice is largely in service of and circulates through digital platforms. Design education needs to be responsive to the rise of platforms as the latest transformation of the internet on both practical and theoretical levels. This paper situates a platform education within and beyond communication design to help develop understandings of the mechanisms of platforms, values influenced by platformization, and design implications. The author presents a framework of relevant knowledge structured in a triangular model of design practice, platform literacy, and design experiment, aiming at functioning as a tool for teaching, framing, and making critical inquiries into platforms.

KEYWORDS | PLATFORM LITERACY, PLATFORM EDUCATION, DESIGN EDUCATION, COMMUNICATION DESIGN, FRAMEWORK
1. Introduction

In the post-internet condition, our contemporary social, cultural, and political activities are increasingly platformized — digital platforms are becoming the primary mode of access to the internet, shaping frameworks of networked communications and mediating content and information distribution. A digital platform provides software, sometimes hardware, and service that uses computational architecture to mediate social activities strategically. Platforms crowdsource content production, turn products into services, outsource infrastructures to seemingly light “clouds.” By doing so, platforms capture and control enormous amounts of information and model them into data forms usually out of commercial interests. While contemporary communication design practice is largely in service of platform capitalism, prioritizing the marketing values of platforms, online platforms are also venues for political collectives and activism and have been used as the medium and subject matter for artistic practice to comment and critique. Scholarships of platform studies have been growing, sharing approaches mostly with science and technology studies and media studies. Design education needs to be responsive to the rise of platforms as the latest transformation of the internet on both practical and theoretical levels.

The need for teaching multi-platform design is a consensus view of the discipline. However, new technologies and creation tools are often celebrated without criticality. There has not been a sufficient common understanding of what content and skills would contribute to an adequate platform education. Developing an appropriate approach for design discipline to engage with platform literacy and platform education is imperative. What skills and literacy are required to make informed design, challenge conventions, or subvert platforms? How might we question the value underpinning and consequences of digital platforms? How would practice-based projects investigate the mechanisms, ethical issues, environmental costs influenced by platformization? This paper situates platform education within and beyond communication design and proposes a framework of how relevant knowledge and skills can be structured and extended.

2. A New Literacy in the Age of Platforms

While education has long been advocating media literacy regarding interactions with mass media, the internet has transformed information distribution modes. The post-digital, post-net culture has dissolved the difference between mass distribution and limited distribution (Manovich, 2001) — mass culture and subculture can circulate in a similar way now that digital content has the potential to reach a mass audience. With Web 2.0, the consumption of information and culture is no longer limited to passive viewership as in monolithic mass media. The involvement modes have expanded: we are both the audience and the driver of the media (Vierkant, 2010).

The term “platform” has emerged since the first decade of this century, describing online services of content intermediaries such as YouTube and Google, which provide storage, navigation, and delivery of digital content (Gillespie, 2010). Technology companies
strategically chose to use the term “platform” for their services, benefiting from its etymological and metaphorical characterizations of flat, neutral, and open to all (Gillespie, 2010); however, platforms are not just distribution channels. They are mediators that produce social interactions and structures and are ideological by design. Platformization had granted the platform owners much social, political, economic, and cultural power, and caused controversies around their datafication, commodification, and selection practices (van Dijck et al., 2018). The relatively recent academic field platform studies has gained popularity after the MIT Press published a book series named after it. The book series conceptualizes a form of investigation into “the foundations of digital media, [...] both hardware and software, that developers and users depend upon for artistic, literary, and gaming development” (The MIT Press, n.d.).

The evolving media landscape prompts educators at various levels to advocate for new forms of literacies, even though these concepts in existing literature are still ambivalent. Media literacy expands to include new strains such as digital media literacy, social media literacy, adapting to changing communication technology, and intersecting with digital literacy. To be literate entails the ability to “critically consume and creatively produce” content in these digital environments (Smith & Kumi-Yeboah, 2015). Digital media literacy can be defined as “the acquired ability to understand, access, evaluate, and analyze types and avenues of information created online or with available software and hardware to communicate and participate in civic life as competent media consumer, contributor, and creator of media in the online community” (Chilsen, 2015). Platform literacy is used interchangeably with media literacy, digital literacy, and social media literacy in an adult education context (Creelman, 2018), emphasizing digital technologies usage and participation on platforms. The term platform literacy occurs in the literature of cultural studies and digital scholarship (Christie, 2016; Jules et al., 2018) but lacks elaboration and definition. Annette Vee argues that every communication form relying on digital media is built on a platform involving computer code and refers to both writing and programming as platform literacies that provide contemporary communication foundations (Vee, 2017).

Expressions of the urgency of platform literacy also appear in informal communications such as blog posts produced by scholars and educators with aspirational goals (Caines, 2018; Carrigan, 2018; Varis, 2017).

This paper argues that platform literacy goes beyond the level of participation to include critical understandings and potential interventional and subversive usages of platforms. Despite becoming marketing venues, online platforms are also venues for activism. Social networking sites and the hashtag’s aggregative function have attracted both marketing campaigns and political collectives to coordinate the publics through these digital platforms (Bernard, 2019; Bruns & Burgess, 2011). Though with different intentions, by sharing the adoption of hashtags, ironically, as communication theorist Nathan Rambukkana states, “at least in this one way, neoliberalism and activism might be speaking the same language” (2015, p.42). Jonathon Hutchinson argues that digital activism needs to learn from its commercial counterpart and adopt similar strategies (Hutchinson, 2019).
The configurations of platforms also shape knowledge production, as computational power has been incorporated into fields other than computer science, such as biology, data journalism, digital humanities, digital activism. Proprietary platforms permeate everyday teaching practice — communication, file organization and sharing, and slide-aided lectures. Tailored learning management systems and other academic computing tools involve platform-building by the education sector. Educators should engage in platform literacy and become aware of the values embodied, and address accessibility, equity, and inclusion issues.

To develop such platform literacy involves understanding platforms:

- The intended use, actors involved, values embodied, and the conflicts of interest;
- Operational principles and mechanisms;
- Material and human resources involved in production and operation, issues of ethics, labor, and the ecological cost;
- Governance through technical features and terms of usages;
- Algorithmic content moderation, how certain types of content are amplified and others are suppressed or censored;
- Datification practice, how activities are encoded into data and users’ control over what has been collected and shared;
- Commodification practice, what is monetized and awarded;
- Influences over values such as privacy, accuracy, and safety.

With these understandings, informed participation and resistance to power become possible. Design practice in a platform society is not limited to the delivery of pragmatic legibility and functionality and can engage more actively and critically in the discourse and shape alternative visions. This paper proposes a platform education that prepares designers for working within and from the system and civic engagement. A platform education for design rethinks the role of design in the system, uses design to render the systemic power and authorities visible, and additionally examines the impact of design choices. Designers are obliged to understand the cultural and political underpinning of the service, interaction, and interface design; feature landscape shared across different platforms and the norms formed as a result; expected use environment and unexpected usages; assumptions the design embodies.

3. A Framework for Platform Education

This framework incorporates precedent sources from social-scientific and media-theoretical studies into an area called platform literacy, emphasizing a design perspective. Design practice and design experiment address the practicalities and speculations with design-specific concerns. The three areas of studies form a triangular model, inspired by the Fallman triangle for interaction design research (Fallman, 2008). The following sections introduce the content and learning activities involved in each area.
3.1. Design Practice

This area is concerned with foundational skills and the implications for professional design practice. The learning activities in this area are mainly understanding and applying the tools, processes, and strategies relating to designing for platforms. The design language of representation and narrative is addressed. Students explore emerging creative technical processes and move beyond visual forms to think about the multidimensions of narrative media: linguistic, acoustic, visual, static, kinetic, spatial, and temporal (Ryan, 2003). Concepts related to experience design, such as continuity and consistency, are introduced. Students build understandings of design systems, adaptive, responsive, fluid design, and experience and journey mapping.

This area also reflects on platforms’ consequential influences on design rationale, visual identities, and visual culture. Google redesigned its visual identity in 2015, for instance, to achieve efficiency and cross-platform consistency even under limited internet connections. The geometric forms of the logo allow for algorithmic image generation based on screen scenarios and significantly reduce the file size (Cook et al., 2015). Data constraint became a design logic. Additionally, visual systems of technology companies do not operate discretely; they embed within each other. Apple News and other services using Accelerated Mobile Pages distill content from sources and display outputs in their own styles. Identity design faces a new set of relationships, as “platforms subsume and dictate other brands’ signifiers” (Viloro & Hamamoto, 2017). As platforms create unstable and complex communication environments, some identity design practitioners assert that launching a static style guide

Figure 1. The triangular framework and key areas of discussion.
with a reductive approach of modernism is obsolete and that identities should be reconceived in terms of adaptivity and flexibility. An alternative bottom-up approach recurs in these discourses, in which a visual language is developed over time, and the brand is collectively built (Other Means, 2017; Viloro & Hamamoto, 2017). Activities in this area are less concerned about being subversive and more about learning best practices and practicalities of working within the constraints of platforms.

3.2. Platform Literacy

While design practice develops literacy to design for platforms, platform literacy instigates literacy to unpack the mechanisms of platforms and make critical inquiries. Influences from other disciplines are most visible in this area, especially from science and technology studies and media studies. Referencing and adopting other disciplines’ theories, methods, and techniques, this area’s content moves from mass media to post-internet discourse, and finally, to platforms and impacts. Concepts in media studies such as media language, representation, consideration about the audience, and institutional influences are still relevant today with expanded participation modes in communication. The traditional notion of medium used to describe the material used in artwork — painting, works on paper, sculpture, video — is not sufficient to categorize contemporary work. New genres, such as multimedia and net art, generalize the work by the technologies involved and provide no additional context. Lev Manovich emphasizes the role of software in the creation and perception condition of a message in the communication chain, treating software as objects of cultural analysis (Manovich, 2001). With creation and perception condition in mind, students explore the taxonomies of communication beyond medium labeling, finding ways to describe the attributes through these example dimensions:

- **Creator and audience size** — one to one, one to few, one to many, few to many, many to many;
- **Distribution mechanism** — the TV network, museum and gallery exhibition, online video, podcast;
- **Active senses** — sight, hear, smell, touch;
- **Action types** — active, passive, interactive;
- **Roles** — producer, consumer, facilitator, performer;
- **Level of control** — the ability to skip the advertisement, pause, or rewatch.

Integrating perspectives from platform studies (Bogost & Montfort, 2007), feminist platform studies (Anable, 2018), and critical technocultural discourse analysis (as cited in Davis, 2020), platform literacy looks into both the things and the bodies involved, and the meanings produced. The study will reveal the often-overlooked physical consequences of infrastructures: submarine fiber-optic wires, dispersed data centers, energy consumption for running and climate-controlling the servers, spaces designed not for human occupancy but...
hosting machines. Then by placing humans back into the systems, we can discuss the labor involved in platform development and electronic assembly and introduce concepts of identity and intersectionality.

Besides unveiling the underlying material and human resources, students examine platforms as design and cultural artifacts. For example, the short video sharing platform TikTok’s home screen is filled with content to watch even without following any creator. The algorithmic recommendation mechanism is actively learning about user engagement and instantly flows the feed with content. With an endless scroll, the platform is designed to increase interaction, attention, and time spent. While these observations are reflected on by cultural journalism (Herrman, 2019; Tolentino, 2019), a design specific approach borrows the walkthrough method, App feature analysis, and value reflection (Davis, 2020) to interrogate the design choices, such as the choice architecture and dark patterns. Students reflect on the operating model, datafication and commodification practice, and the underpinning values.

Platforms can simultaneously have characteristics of two conceptual extremes and paradoxical positions. The following attributes demonstrate standpoints from which to interpret platforms:

- **Platform as centralization and decentralization.**
  After the release of smartphones and app stores, internet access has been dominated by mobile devices, and the decentralized early web has been replaced by hegemonic platforms and apps with specific functions. Information produced on the platforms tends to stay within the platforms as they are not indexed by search engines and thus not openly accessible. The information centralized on proprietary platforms is unstable and difficult to archive. These challenges of long-term storage and preservation of information lead to the creation of a digital dark age. Online platforms often employ user rating and algorithm-driven recommendations, which seem more democratic and can be seen as a challenge to centralized institutional power. However, the selection and sequencing strategies are also based on commercial reasons and controlled by often black-boxed algorithms.

- **Platform as empowering and disempowering.**
  Platforms provide frameworks that give people space for public voice. Features such as hashtags, TikTok challenges, and memes provide structures and invitations allowing the exchange and aggregation of individual messages. Format limitations also create shared syntaxes, which in turn facilitate circulation. This phenomenon is not entirely new to the digital world. The “John & Paul & Ringo & George” t-shirt designed by Experimental Jetset commemorating Beatles members has become an archetype, causing many bootlegged versions tributing to other groups. These structures and formats can help with the formation of the public sphere, bringing statements together, and forming collectives. While raising visibilities to individual statements, such a format has a risk of leveling individual experiences. Over the course of the #MeToo movement, the usage of
the hashtag has raised criticisms for homogenization and suppression of unique voices (Bernard, 2019).

Customization capacity alludes to a sense of empowerment. According to YouTube CEO Chad Hurley, “the online video experience is about empowerment.” Content owners, consumers, and advertisers are empowered through tools of data and the ability to customize to their needs (Hurley, 2008). Platforms can shift economic powers from legacy institutions to individual users by allowing individuals to market personal assets and profit from them (van Dijck et al., 2018). On the other hand, user-generated-content platforms rely on users’ contributions of time, labor, and risk-taking. While people have quit their day jobs to become full-time bloggers, the platforms share little risk but have much power over controlling the terms, interface, and algorithms. Participating in this economy as influencers, drivers, or hosts, could bring economic returns. At the same time, the user-contributors bring more traffic to the platforms, which ultimately benefits the platforms and leads to a concentration of power in the hands of the platforms.

- **Platform as neutral and ideological.**

The word platform’s connotations of flat and neutral are of advantage to actual value-laden platforms. Even though content intermediary platforms position themselves as “empowering all but choosing none” (Gillespie, 2010), platforms govern their users by user agreements and policies. Sometimes, the actions can be contradictory to their statements. For example, YouTube videos with LGBT content trigger the algorithm to restrict and demonetize the posts, stopping them from earning ad-based revenue. Since platform operation relies on computational power, many aspects of the world that have never been quantified before are now facing datafication (van Dijck et al., 2018). While often considered as an impartial representation of reality, data can hardly be objective, as one common critique for big data says: “‘Raw data’ is an oxymoron” (Gitelman, 2013). When setting up the gathering mechanisms on a platform, data are already prefigured (van Dijck et al., 2018). The collected data must be interpreted where specific interests come into play. When it comes to cataloging, filtering, and presenting the data, algorithms are created by humans who can bring their implicit biases and values into the code (Noble, 2018). For example, Facebook adopted a spectrum of gender identities for its users to customize their profiles. While its user-facing interface allows nonbinary identities, at the database level, this information is still kept as a male–female binary for the use of advertisers (Anable, 2018). Platform operators are also increasingly vocal in policy and law-making (Gillespie, 2010) and can influence social–political movements in various ways.
Platform as private and public spaces.

Platforms are often private-owned entities acting like public spaces. They appear to be a barometer of public sentiments, especially with hashtags, to create ad hoc channels (Bruns & Burgess, 2011). Platform operators control the interface and algorithm that facilitate information exchange, expressions, and discussions and could shape public opinions — take the Facebook–Cambridge Analytica data scandal, for example. The firm collected personal information of millions of Facebook users without their consent and modeled voter profiles, which became subjected to targeted political campaigns.

Awareness of the need for the protection of the digital public space has been growing. In October 2017, Snapchat partnered with artists to create geo-tagged 3D sculptures to be viewed in augmented reality at specific locations via the Snapchat app. The project launched featuring Jeff Koon’s Balloon Dog in Central Park, New York. Although the AR work is presented in physical public space, the work and the digital public space are still protected within a space controlled by a corporation. The corporation received criticisms for contributing little to maintaining public spaces but benefiting from the publics formed at these spaces and the marketing effect. Within a day of the launch, artist Sebastian Errazuriz and the Crosslab team released a standalone free app with a vandalized version of the Balloon Dog covered with graffiti as an act of protest. The vandalized identical Balloon Dog accentuates the private nature of the digital public spaces. The artist sees this as a “symbolic stance against an imminent AR corporate invasion” (Errazuriz, 2017).

This area engages with current societal and ethical issues, such as authority, power, labor, climatic cost of technology, security and privacy, and cyberbullying. Ultimately, this area aims to build an intellectual tradition and form a unique approach appropriate to the design discipline.

3.3. Design Experiment

Design experiment reflects on the responsibilities of the designer and focuses on the propositional power of design — the construction of a different reality that challenges colonization, makes space for speculation, and provides possibilities for powershift. The activities in this area require synthetic skills to evaluate and to create. Integrating thinking informed by platform literacy and practical skills acquired through design practice, design experiment uses discourses around platforms as the subject matter or uses it as a medium of practice to produce artifacts, experience, or systems as provocations. In contrast to design practice, which works within the system, design experiment involves expanded and emerging modes of practice, sitting at the fringe or outside of conventional commercial design. Instead of being market-driven and following the paramount of best practice, works in this area are more exploratory, producing critiques of the current state and experimenting with subversive or alternative ways of using platforms. While speculative design and critical
design are precedents of alternative modes of practice, design experiment is not limited to producing tangible techno-critical objects. The outcome of this area can take the form of visualization, social campaign, design for advocacy, installation, and participatory activity, and can situate within the context of platforms as the medium of dissemination. The activities are problem-setting rather than problem-solving. While experimental projects cannot solve the dilemmas present in the platform age, by engaging in various creative actions such as treating platforms as performance venues or developing tools for misuse and subversion, design can reach the audience in original means and build awareness, frame discussions, and promote engagement. Ultimately, these efforts can influence design practice at large to be “calibrated towards a systematic redistribution of power and wealth” (Viloro & Hamamoto, 2017).

4. Application of the Framework

The different sets of goals in these areas ask students to change their perspectives and challenge them with different works while exposing them to various modes of practice. In using the framework, teaching activities move in-between areas. Learning about design practice and platform literacy informs each other and is synthesized towards design experiment. Through the lens of reflective practice and research through design (Frayling, 1994; Schön, 2017), what is learned in the design experiment area will contribute to the cumulative knowledge of platform literacy.

The framework presented has been formulated when developing a junior-level studio course in a Communications Design curriculum. As a tool, a draft version was used during conversations among faculty when coordinating multiple course sections. The framework has guided the planning for projects, reading materials, and in-class activities. It has also been used as a student-facing roadmap to the course, helping establish connections between different course content areas. It can guide rubrics for course assessment and student work evaluation. It has proven useful for establishing a common ground and articulating and clarifying terms and skills relating to “platform.”

The framework has been integrated into the class as a series of workshops, lectures, and three major projects: design for, with, and about platforms. “Design for platforms” follows the constraints and specifics of platforms like how they would be used in the industry. “Design with platforms” interrogates the functions and paradoxes of platforms. Students use and subvert a platform, experimenting with assigning the platform a characteristic that was not a part of its original design and employing the platform as the medium to manifest the concept. “Design about platforms” reflects on the impact of technology, media, and platforms and uses the related contemporary issues as content to design for advocacy and public engagement. The outcome is a social campaign with participatory and installation components.

The first run of the assignments tested that there are overlaps between “designing with” and “designing about.” When subverting the platform, it is still “designing for,” in the same way as digital activism using platform marketing techniques. The design experiment could have
been pushed to include speculation of new platforms and alternative ways to operate current ones. From class observation, although students are critically engaging the discourse, the technical and intellectual skills desired are hard to acquire from one single course. These concepts introduced are not contained in one course and can build continuity and knowledge transfer between courses. At the departmental level, platform education could inform larger curriculum updates, incorporating learning goals into multiple courses and advancing over time.

The framework is still under experimentation and refining, and the projects observed will inform further iterations. Future development of the framework involves analyzing past class versions and stimulating conversations around platform education and soliciting feedback. The framework provides scaffolding for a platform education in design. It aims to clarify terms and produce an organizational structure of skills related to consumption, evaluation, and creation in the age of platforms. Advocating for a platform education to respond to the intricate contemporary media landscape, this paper aspires to begin a conversation and foster discourse about teaching, framing, and making critical inquiries into platforms.

References


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The body as an artefact: a case of hand prosthesis

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Abstract | The tension of overcoming our biological limits - as human beings - is the driving force in our evolutionary history. Since ancient times, we have used technology as a solution to overcome our limitations: the invention of clothes allows us to adapt to any climate, the spectacles empower our sight.

Today, technology is even more powerful: technical suits support us in visiting extreme environments, including the emptiness of space, where humans cannot survive. We are surrounded by artefacts placed on the body (i.e., wearables, oculus), in the body (i.e., endo-prosthesis, diagnostic and therapeutic aids) and in the extended body area (i.e. non-invasive medical devices, robots for surgery etc.)

This paper aims to highlight some of the challenges raised by the relation between the human body and extra and intra-corporeal technologies, focusing on the design of a multi-jointed prosthetic hand, discussed with regards not just to functionality, but also to aesthetic and mode of use.

KEYWORDS | EMBODIED TECHNOLOGY, CYBERNETIC BODY, PROSTHESIS DESIGN
1. Introduction

Today's technological progress has extended the capabilities of human body, for instance by enhancing our senses or our strength. Novel applications in the fields of ICT, biotechnology and AI are giving life to unexpected scenarios and possibilities. Also, a new advanced generation of prostheses seems to promote an evolution toward empowered bodies. So, while the advancement of the digital world seems to suggest surpassing the body’s materiality, dissolving it into virtual realities, we are also assisting to a revaluation of physicality. Indeed, the development in fields such as bioengineering and aesthetic surgery has brought into question the organic nature of the human being, paving the way to the advent of a hybrid being with inedited technological characteristics. In this scenario, the body becomes the outcome of a project: it becomes an artefact.

In the light of this evolution, the role of design is challenged by devices that integrate with the body in different manners, from inside to outside. In the inner body area, we find invasive biomedical devices such as endo-prosthesis, diagnostic and therapeutic aids. In the external area, instead, there are devices that interact with the body in such a way that users are aware of them: eso-prosthesis, diagnostic and rehabilitative aids. Finally, in the extended body area, there are non-invasive medical devices that integrate biosensors, telemedicine communication systems and so on.

This paper focuses on the design challenges faced by designers who deal with such “human tech-empowered” artefacts, while aiming at fulfilling the requirements of aesthetics, mode of use and performance, but also considering ethical issues.

We analyse as a case study the awarded design of a multi-jointed prosthetic hand, called Hannes, developed by DDPstudio in collaboration with Istituto Italiano di Tecnologia (IIT) and INAIL Centro Protesi. Hannes is able to give amputated users more than 90% of the functions, thanks to the naturalness of shape, movements and orientation of the rotation and posture axes. The control system implements both traditional strategies and new strategies based on AI algorithms, with which people can command movements simply by thinking of what they would naturally do. The personalization of the operating parameters takes place through a specially developed software which interfaces with the prosthesis.

The prostheses of hands, together with those of legs, well represent the complexity of these design challenges. On one side, they have extremely intricate functionalities to perform. They play, indeed, a crucial role in the replacement of lost abilities, but also - and possibly most crucially - in the definition of individuals’ identities. As a result, designers have to always fulfil the highest requirements of users with regards to both functions and performance from one side, aesthetics, experience and meaning from the other.

Nonetheless, as designers, we ask ourselves what role we should play in this fascinating path and which ethical limits we should set to it.
2. Human Beings and Technology: A Contrasted Relation

The tension of going beyond ourselves, to overcome our biological limitations is the driving force that has guided all the technological progress in human history. Since ancient times, indeed, the application of technology serves the purpose of modifying and mastering the external world for our benefit.

Donald Schön (1967) defined the “extension of human capabilities” as the main goal of technology itself. Verbeek (2005) added the principle that technology is not something that humans work with, but something that is part of being human. It is therefore not surprising that, after producing a large mass of external instruments, we aim now to perfection and to extend the capacities of the body itself. A lot of us are already walking, manipulating objects, or just being alive, thanks to external prostheses and internal installations, such as metallic bones, artificial veins, microcomputer and similar devices installed in our organism. (fig. 1)

Figure 1. On the left: Hyundai Exoskeleton; In the center: Reconstruction of a hip through metallic bone; On the right: an example of human microchip implant.

Today, neurostimulators can be surgically placed under the skin, so to control movement symptoms such as tremor, slowed movement and stiffness due to Parkinson. At the same time, exoskeleton powered by motors and pneumatics allow limb movements with increased endurance. Our bodies are being permeated by technologies, becoming a mixture of natural and artificial (Fortunati et al., 2003). Nevertheless, this pervasion of technology into the human body has always been one of the most difficult steps of our evolution to be accepted.
Emblematic in this respect is the dystopian narrative of technology proposed in the novel “Frankenstein” by Mary Wollstonecraft Shelley, edited for the first time in 1818. Victor Frankenstein can be seen as the modern incarnation of Prometheus: he, as Prometheus, is fascinated by the power of the modern version of fire, electricity. Right after the birth of his creature, Victor is both fascinated and tortured by the power of his creation, ill with disgust for what he has done. “Frankenstein” is the first novel that reflected the characteristic condition of modernity, that had capsized the temporal perspective centralized on the past, typical of the pre-modern societies, to promote and emphasize the drive to the future, that had its fundament in the idea of progress. However, Victor Frankenstein represented the wicked scientist who used new techniques to overcome death, the ultimate of human limits. The outcome of his experiment was, at that time, inhuman and unacceptable: Victor’s torture mirrors that of Prometheus, guilty of having stolen the fire from gods: a torture that, for both of them, has to be undying and eternal.

Nowadays, we are perhaps ready to embrace the technologization of our body, at least as long as such technologization replaces/cures/supports/monitors us for a better living. Following this, captivating is the story of Neil Harbisson, recognized in 2004 by the British government as the first cyborg in history. Born with acromatopsia, he is uncapable of seeing the full spectrum of colours. Today, thanks to an antenna- the eyeborg- implanted in his skull, he is able to hear the colours transformed into sounds.
Technology has finally entered us. It penetrated our mental and physical structures, interbreeding the body. We are shifting to an updated image of “cyborgs”, where – thanks to an embodied technology - the human body is wholly engaged. (Hollinger V., 1999).

3. Redefining our Identity: The Updated Cybernetic Body

Technology has the task to provide for the inadequacy and imperfections of the human being, not only to substitute missing organs, but also to boost them up (Gehlen, 1980). The resulting “mutant” body (Fiorani, 2004) is a communication-body, amplified and dilated by external and internal prostheses, shells and shelters. It is a body extended until it becomes a sensing network, a body empowered by sensors and digital archives inside its clothes and prostheses (Pacifici and Girardi, 2001).

In this perspective, identity itself is being re-defined. We are indeed witnessing the evolution of our identity from a body that uses technological instruments, to a body that becomes technology (Pecchinenda, 2010). In this mix of body and technology, the body becomes an instrument by itself. Even better, the body re-designs itself into a hybrid bio-technological being. A human being that co-habits and interacts with technology, so much so that it integrates it in its own perceptive and sensorial apparatus up to the point of fusing completely together. A human being that doesn’t abandon her body but elaborates it in the name of an artificial ideal that allows her to overtake her biological limits. (Bell et all. 2004)

We can therefore affirm that our digital society finds itself facing two opposites but complementary trends: on one side, a devaluation of the body in the affirmation of our identities in the virtual realm; on the other side, a revaluation of the body that - thanks to the development of medical and technological research - opens the door to novel perspectives. From biogenetics to plastic surgery and body-art, the biological body is questioned, but not to be abandoned. On the contrary, to be improved and perfected. (Kastrup, 2018)

Paralympic athletes can today compete thanks to the availability of advanced prosthesis. These devices are sometimes so performing to enable them to achieve results like able-bodied athletes.

We all remember the notorious controversial case of Oscar Pistorius who, although had both legs amputated, was hypothetically able to compete with able-bodied runners, thanks to a set of special carbon fibres prostheses. The South African athlete even asked to join the Olympic games, but he was not allowed to, because such prosthesis might enhance his performance beyond human range. So, the prosthesis allowed him, not only to “repair” his disadvantage, but also to “increase” his performance. (fig. 3) Had him been allowed to join the Olympic games, it is likely that able-bodied runners would have liked to (or would have had to) enhance them-selves too with carbon fibres prostheses, starting a new rush toward
becoming super-athletes. In this perspective, the competition would be based more on technology than on human performance.

Figure 3. Pistorius Prothesis

In this specific case, something crucial would be lost of sport competitions which, being based on the same context conditions, try the different human characteristics. These kinds of conditions highlight how different we are, one to another, and how important is the role played by our body in this comparison. It is thanks to the body that everyone is exactly who she is: a specific individual that enters in relation with others, a unique “me” that recognizes in the other a “you” equally unique. Would it still be possible to be “unique” in a world of super-heroes, made of bionic bodies and perfection? In the basic postulate of post-humanism, the selection of the physical characteristics, that we desire to develop, would be better than letting nature go its way (Ferrando, 2016).

We do not just permeate our body with devices, but we change it with aesthetic surgery, and other techniques (not always as invasive and permanent), because of the illusion of stopping time and its effects on our natural physical deterioration. We follow an ideal of a perfect organism, as if imperfections, that makes us who we are, were inconveniences to be solved (Putrov, Galina, 2018).

Technological evolution enables this race toward the continue redesign of our bodies. Will that lead us to the point where we will be given the choice to replace our body’s parts not just because of accidents or diseases, but just to constantly improve our aesthetic and performance, in a sort of continuous update of ourselves?
In the light of this open question - the answer to which is yet to come- being experts in design and technology we wonder which kind of approaches should we take on while facing this class of artefacts.

For sure, designers have (and should have) the sensitivity to address issues by meeting not only technological requirements, but also user needs with a human-centred approach. Indeed, nowadays, we can find products designed to be placed on the body or for the extended body area that consider aesthetics, functionality and - even more importantly – the human perception of technology. These are products in which the technology enhances users in a pleasant, acceptable way, rather than just replying human abilities (Ferraro, 2012). Examples are wearables that can be worn unobtrusively on the body as clothes or devices that, substituting traditional products, become real extensions of our body. (fig.4)

Figure 4. On the left: Superflex Skeleton (augments different level of mobility in older people); On the right: Chairless Chair (enhance healthy position)

As designers, we don’t believe into a technology that substitutes “humans” making us “inhuman” (dystopian view). We prefer instead a positive view, where humans become (acceptably) augmented (utopian view). (Bernat, 2013)

4. Hannes, a multi-jointed prosthetic hand

While we face these issues about the human relation with technology and its future perspectives, we can detect what are the latest achievements when it comes to products designed to be placed “intrabody” and see if they confirm or not our assumptions.
As a case study, we analysed a multi-jointed prosthetic hand, called Hannes that in 2020 was awarded the international industrial design prize Compasso d’Oro. Hannes is able to give users, who had the limb amputated, more than 90% of the functions, thanks to the naturalness of shape, movements and orientation of the rotation and posture axes.

The control system implements both traditional strategies and innovative strategies based on AI algorithms, with which people can command movements simply by thinking of what they would naturally do. The personalization of the operating parameters takes place through a specially developed software which interfaces with the prosthesis via a Bluetooth connection. Hannes was developed by DDPstudio in collaboration with Istituto Italiano di Tecnologia (IIT) and INAIL Centro Protesi. We interviewed Gabriele Diamanti, member of the design team together with Lorenzo De Bartolomeis and Filippo Poli, to find out the characteristics of the device and more.

Question (Q): “What is the level of development in this field of myoelectric prosthesis?”

GD: “There are many of them on the market, but not really satisfactory. When they are functional, they are disproportionate or ugly, while, when they are more aesthetically pleasing, they are not as functional. That is, they are usually too unnatural in the movements, sometimes too weak or too heavy to be really used in everyday life in a profitable way”.

Q: “What are the improvements of Hannes compared to other devices?”

GD: “With just one engine for all the fingers (and therefore less weight and lower production costs), Hannes manages to be compact, slim, light and beautiful. It can adapt to the shape of objects with a unique naturalness and when necessary, exert a high force”.

Q: “What is the role of designers in such a technological product development?”

GD: “The pivotal understanding that technology alone is not enough is thanks to IIT and Inail. They realized that they needed design to make a robotic arm “human”, so that an object that is very useful but usually not accepted by users for aesthetic/ergonomic reasons, may finally become desirable and really used every day, changing people lives. It is for this reason that we, DDPstudio, were asked to collaborate with the Rehab Technologies INAIL - IIT Lab, something which we are very proud of.”

Q: “In which stage of the development your studio was asked to interact and collaborate with the engineering team?”

GD: “The hand for which the mechanics were developed was originally for robots. It was then transferred, as a spin-off, to the idea of prosthesis. At that point we, designers, were involved in the project. From that moment on, we worked together with the engineers through an iterative and collaborative approach.”

Q: “While working in such a multidisciplinary team did you find yourself struggling with technicality? If yes, how did you face it?”
GD: “Our collaboration with engineers has been very close and positive. Indeed, the success of Hannes originates also from the way we worked. We took the best of the different disciplinary inputs.”

Q.: “Hannes robotic hand is aesthetically very well-finished, but does not imitate the real hand (skin, hair, etc.). Why is that? Is it easier to accept?”

DG: “All robotic hands – Hannes too – are covered with a customized glove (usually made of silicone or PVC) which acts as a skin. The glove simulates the skin tone of the user and it can have realistic nails, even the hairs. Yet, Hannes imitates the human hand in the most important aspects: the shape, the proportions, the dimensions, the postures it can assume, the resting position, the movements it makes (axis of rotation, range of motion), and the response to the grip (which is adaptive). As regards for aesthetics, these are all factors that in everyday use - count much more than simple cosmetics. Nevertheless, while typically users prefer a hyper-realistic prosthesis with human looks, there is now an emerging tendency (especially in the Anglo-Saxon countries) not to conceal the prosthesis anymore, but to show it as it is, enhancing its technical appearance. Therefore, having an aesthetically nice robotics hand, which explicitly declares itself for what it is, constitutes an added value and makes it possible to satisfy the demands of this emerging slice of the market. Indeed, even our “patient zero” (a man who is using Hannes to test it), likes to wear Hannes as it is, without the glove. So, for this reason, we gave him a transparent glove, that protects Hannes during intense or wet usages, but shows its high-tech aesthetics. Finally, we believe that a well-done design should be beautiful even under the skin, literally.”

**Figure 4. The hand Prothesis “Hannes”**
Q.: “Then, how did you design the aesthetic of a robotic hand?”

GD: “To develop the Hannes hand, we studied the shapes and proportions of the “ideal hand”, starting from scratch: from research into the world of artistic representation, to an in-depth study of the anthropomorphism of the natural hand, up to the comparison with the producers of high fashion mannequins, as a reference for the most up-to-date aesthetic standards.”

Q: “While studying the shapes and proportions of Hannes did you develop and test intermediate prototype(s)?

“Yes, there have been six main phases of development. For each phase, we had a specific prototype that helped us to first integrate the design and engineering proposals and then to test the integrated version.”

Figure 5. The several stages of development of Hannes.

Q: “In doing a robotic hand, have you not been tempted to give it better (than a real hand) performance? Make it stronger, for example?”

GD: “There are still huge technical limitations in increasing the potential of the real hand by making it a hand with “superpowers”. The first is that a larger engine would have to be used, thus exceeding the dimensions of the natural hand. The second is that the life of the batteries, which is a fundamental requirement for everyday use, would have been severely limited. Of course, we had that temptation, but the real hand is such a perfect thing, robust and functional (despite its slender structure), which is already a miracle if we managed to give Hannes a similar force. Most of the other hand prostheses are indeed much weaker than a real hand. Yet, another interesting concept would be to increase the number of
fingers, or to decrease it, or to attribute to fingers some movements that are impossible to real fingers. These are all possibilities that emerged in the brainstorming phase and have been useful for carrying out the work, but they never passed the conceptual stage because the anthropomorphic requirement is too important for users. Indeed, 99% of them would not accept something clearly different. We must remember that we are talking about people who are already used to feeling different because of a disability, so, typically they wish to go back to normal, not to be more different.

Another opportunity, that was discussed in focus-groups with potential users, is to integrate the prosthesis with existing electronic devices. For example, if you have an arm amputation in the forearm, there is an extra space in the prosthesis where it could be possible to put a smartphone, a smartwatch, etc. Hypothetically, users are interested in interacting with everyday electronical devices, but this option is extremely secondary to the practical needs they really have. Thus, research is still focusing on making the prosthesis performs at best the complex functions of the human body.

Q: “It seems to us that we are expecting a future in which various forms of devices will integrate ever more effectively with our bodies. Through the Hannes experience, what is your idea about the future? I mean, do you think it will be normal and accepted that our bodies will become “cybernetic”? What role will this evolution play in the definition of our individual identity?”

GD: “It will be absolutely normal for our bodies to be cybernetic. This is not even an anticipation of the future, but the observation of a consolidated reality. After all, isn’t a pacemaker carrier already a cyborg? We never think about it, just because we do not see it with our eyes, but it is so. The eyeglasses, on the other hand, are an example of “put on and off” prosthesis not integrated with the body, but which is a proper prosthesis: it gives back power and effectiveness to a weakened function. And they have existed for centuries. In this sense, they are not different from cheetah legs (the one wore by Pistorious) or a myoelectric prosthesis. The fact that we perceive them as normal is simply a matter of cultural evolution, that always takes place through everyday use. Thus, the more these plug-ins will be useful for carrying out essential daily tasks, the greater and faster will be their acceptance by the users. That is: being a “cyborg” will be perfectly normal, when it will allow users to have a normal life. At that point, there will be (and the first signs of this tendency are already present) the wish to play with a prosthesis, to personalize it, to make it closer to one’s taste. Like for the eyeglasses frame, the arms and legs are becoming a field of aesthetic, of use and constructive experimentation. That is, a design field.

Completely different is the topic of body augmentation, that is the implant of prosthetic by able-bodied users to add functionalities that the body would not have in nature. We believe that, in the near future, this theme will remain in the field of cyberpunk mythology and experimentation by some avant-gardes (like the case of Harbisson, who – to be fair – is not an able-body). It is not just a problem of social acceptance, but personal: it requires a very strong motivation and real needs.”
We have described the design of an advanced robotic hand that reaches the highest requirements of a typical user - as regards for functions, performance and aesthetics – but also fulfil a new trend, where the user displays her prosthesis proudly. In our understanding, this new trend anticipates a turning point where users will not hide their cybernetic body anymore, they will rather show it, customize it, improve it.

5. Conclusions

The development of increasingly sophisticated solutions for repairing/enhancing the human body is based on the progress in all the fields of technology and – more in general – in applied medical sciences, but it has repercussions - on a more philosophical and ethical level - on the fundamentals of human existence.

The possibility not just to heal our body, but to increase its performances, challenges the way we determine our identity, our essence. Yet, we do not abandon our own “physical container”, rather we revaluate it and hybridize it through technology itself, in pursuit of new standards of perfection and uniqueness. This way, the human body becomes a working artefact that embraces the use of prostheses and other instruments that extend our motoric, manual, intellectual and sensorial skills.

In this perspective, all devices that start to become part of it (the body), are likely to evolve towards a system of physical prostheses, also able to elaborate data and to supply services. It is a body to re-consider and to re-design.

Eventually, we can nowadays experience what Wiener defined as “cybernetics” in his influential 1948 book: the convergence of digital, mechanical and biological. While emerging technology is rapidly getting intimate to the human body in shape of various artefacts, design researchers and practitioners are facing several challenges, all pointing towards ethics, since nowadays two opposite approaches toward technology coexist, the utopian and the dystopian one.

In the light of this perspective, while dealing with technological artifacts and working into multidisciplinary teams, designers have the role of reasoning on a broader view of technology encompassing aesthetics, user experience, meaning and social acceptability of such newly designed artificial bodies.

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The design of human machine interfaces: from data to risk prevention.

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Abstract
The paper focuses on interactive design with a specific focus on the human machine interfaces for the risk communication. The paper shows the results of an ongoing research based on a double approach: a critical approach addressed to the definition of a cultural perspective for the design discipline in the context of the Informatic environment; an experimental research project based on risk revelation and communication. In the first part the paper gives a perspective based on the comparison, management and organization of the principal theories meaningful for the language and sense of the artifacts. In the second part we refer to the human centre design method. Through a case study the paper exposes the theme of data derived from devices in order to detect risk and communication. Good for risk prevention will be detected by the effective role of the human machine interface, by a complex and multilevel communication strategy.

KEYWORDS | PRODUCT DESIGN, INFORMATION DESIGN, RISK PREVENTION, HUMAN CENTER DESIGN, HUMAN DATA DESIGN
1. A cultural perspective for post digital design

The culture of design that focuses the artifacts in their technological dimension, during the second industrial revolution, has addressed the attention of design towards the theme of the “utility”. The artifacts have been designed in order to respond to the "use on demand" and the technical-physical devices are defined to correspond to this condition. The formal language is articulated properly for suggesting the interaction between man and the artifact on the basis of a predilection for the sensory stimuli of the visual area.

The post-technological culture has, also, enhanced the ability to allocate electronics in the physical body of the artifacts and has, thus, expanded the interest of design towards the theme of the "functions". The artifacts have been designed in order to correspond to such expectations of functioning, going through a human-artifact mediation based on a cognitive approach. The attention of design towards the proximal areas of computer science and cognitive psychology is mainly activated in order to give answers to users’ needs, enhancing the theme of the human-artifact and / or human-machine interface.

The miniaturization of electronic components, then, identifies new constraints in artifacts and high technological content, shifting the focus of the project from the physical apparatus of the envelope of the technological component to their "synthetic" interface, in direct mediation with the user and his capacity to interact with it.

Today, the outcomes of the digital revolution in the IOT are leading the attention of the project towards the theme of the "experience" of use, that is the conception of artifacts that offers new interactive modes between the technical - physical devices (increasingly controlled in the dimensions and material interfaces) and the immaterial dimension. At this connection Krippendorff (2007) discussing on the “experience product” affirms:

"English dictionaries trace the origin of the word, ‘experience’ to knowledge of or skill in making experiments. Its etymology suggests an important conceptual truth: experiences are not merely personal and subjective but crucially related to interacting with something of interest, an artifact, an activity, or a situation involving other people. What we will explore here must therefore overcome the objective/subjective Cartesian dichotomy and be concerned instead with how humans experience the world by acting on it and creating it.

The prefix 'ex-' also suggests that ex-periences require ex-ternalization, ex-pression, or ex-planations. We cannot know what others experience unless they let us know by whatever means are at their disposal. We cannot discuss or theorize experiences without using words. Thus, while the sharing of experiences is impossible, when we talk with each other of what we experience we do so con-sensually, that is, in reference to something jointly attended to – naturally including the discourse by which we coordinate our under-standing and actions. It makes sense, therefore, to say that we shared a taxi ride or listened jointly to a concert, but not that we shared the experiences of these events. The latter may be different for each of us. Similarly, we can hear each other speaking, we may even talk about what we mean to say, but
we cannot share meanings. Moreover, while our experiences are not only shaped and conceptualized by the categories provided to us by our use of language, we cannot help but talking about them in the expectation of being understood, which implicates the interests of sympathetic listeners or the community in which talking of certain experiences is valued. Inasmuch as the use of language is essentially social, what we know of each other’s experiences is, hence, fundamentally social as well, not entirely subjective.” (Krippendorff, Butter, 2007)

This leads to an intersubjective dynamic built on the basis of networks that include both humans and computers in a relational dynamic. Furthermore, in this perspective the artifacts begin to be conceived in order to give answers to that needs not already explicitly expressed by the user, defining a dimension of design culture that puts in direct dialogue the various relevant areas of science responsible for the development of “digital environment”, both that hard and that soft areas. In this context, the design of devices dedicated to the needs of “doing” in a broad sense finds space. Think of the devices created to hybridize functions and define new types of systems: the smart watch in its intelligent extension becomes a system capable of relating the user with the community of devices that connect and are able to offer help in real time. The satellite navigator is a clear example of the application of these technologies: when we move from one city to another, what we see our path with the navigator, we increase the reality we perceive.

Design in the post-digital era therefore proposes a new way of interacting with the environment through artifacts capable of numerically enhancing and expanding the range of human sensory perception through nano-electronic devices - sensors interconnected to systems with computational capacity. The attention that the designer pays to the technical-physical devices is increasingly moving towards the possibility of adequately allocating the computational capacity in things by establishing new forms of intersubjective dialogue between man, artifacts and the environment, both in its size digital (Floridi, 2017) both in its physical and metaphysical dimension.

The research presented in this paper concerns the devices for personal and collective security, as will be read in paragraph 4.

Finally, the cultural perspective that is argued here focuses on the epochal passage, in gnoseological terms, of the meaning of the artifacts and of the symbolic values that express it: to theories that take into consideration the language of artifacts on a socio-semiotic basis (Ellinger, 1966; Burdek, 1997; Gibson, 1979; Barthes, 1983; Norman, 1988; Habermass, 1991; Maldonado, 1961, 1993; Eco, 1968, 1976, 1980, 1984; Krippendorff, 1986, 1989, 1997, 2018) are joining the theories that implement computer programming languages, focusing on data communicability. If the characteristics of the materials, the color, the weight, etc. they are, in fact, part of a structured, non-verbal language, intended to intercept the user’s personal interpretation, intended as a synthesis of the cognitive sphere influenced by the socio-cultural environment and the subjective intuitive remarry on a perceptual-sensorial basis,
the dynamic dialogue of human data with the devices responsible for interpretation and processing on an IT basis opens up a new need for coding languages.

2. Design with human data

The perspective introduced by Big Data in the context of the project of intelligent artifacts pertains, therefore, not only and not so much to the communication capacity of the single device with the single user, as to the wider and more complex communication perspective in the complex of interconnected networks. From the commodity product, which responds to concrete needs of the user (such as computers, tools and appliances), the design integrates and includes the artificial intelligence functions in order to guarantee new safety and well-being standards. In this regard, Norman summarizes three different types of design: industrial, user interaction and experience. Industrial design deals with the creation and development of concepts and specifications to optimize the functionality, value and appearance of products and systems, with the mutual benefit of users and manufacturers. The design of the interaction instead focuses on the way people interact with technology. The aim is to improve their understanding of what can be done, what happens and what has just happened, based on psychological, technical and aesthetic principles. The design of the user experience, which deals with the design of products, processes, services and environments, aiming above all at the quality and pleasantness of the overall experience (Norman, 2014, p.23).

So, for the IoT we take, here, into consideration the so-called smartness applied to objects and places, mainly giving relevance to the possibility to monitoring, control and transfer information for safety sake, as far as so as to be ability to carry out the appropriate consequent actions. In recent years, the use of objects connected to the Internet has become increasingly widespread, both in people's daily lives (wearable devices, connected appliances, etc.) and in the working life (digitized production lines, Industry 4.0, etc.). One of the protagonist segments of this IoT revolution is the industrial one, so much so that we speak specifically of Industrial IoT, which is nothing more than the application of the Internet of Things to the industrial world (Floridi, 2015). Today, wearable computers represent the new world of electronic devices. If worn directly by man, they create the so-called human-machine interaction. Their main purpose is to minimize the number of devices to be worn by man, concentrating as many functions as possible in a single device. In this way, if each person has at least one, it is possible to facilitate his interaction with the outside world and other users.

The epochal passage that includes the dynamics of human data in design constraints opens up a new perspective:

“If in the past we had to think about how people would interact with technology; today we must also consider the point of view of the machine. Creating intelligent machines means creating interaction, symbiosis and cooperation, both with people
and with other intelligent machines. If in the past we limited ourselves to using our products, in the future we will have them more and more often as collaborators, sometimes as it happens, sometimes as servants and servants. We will find ourselves increasingly supervising and controlling, while we ourselves will be increasingly controlled and supervised.” (Norman, 2008, p.168)

The wearable computing technology applied directly to humans, through external devices, does nothing but improve the interaction phase that exists between the user and device. Through their use, the user also involuntarily changes his habits and his behaviour with those around him. The opportunity to make the user able to interact with this device, simply and quickly during every moment of their day and in every place, leads to the creation of a new design method: the persuasive technology (Fogg, 2003).

Persuasive technology is used for the purpose of changing and/or improving human habits and behaviour. Today it is used in various sectors such as politics, health, advertising and marketing, but also in simple everyday life, also interfering with simple interpersonal relationships. This is aimed at changing the way users act and think, through the design and development of IT products. This means that everyday life will be managed by intelligent objects including wearable devices, included in smart fabrics and clothing (e-textiles). Commonly used objects such as sportswear, watches and shoes continue to evolve, as if enriched with intelligent control devices such as sensors, they manage to monitor and control human life, without the latter noticing. Most of these smart devices worn by humans are not developed and created to be used alone, but only work if associated with an App and websites dedicated to it. Wearable devices, objects that are spreading more and more in the current market, can be classified into three groups: complex accessories, smart accessories and smart wearables. Complex accessories are those devices that require connection to another device, such as bracelets used for monitoring physical activity, whose data are readable only after being downloaded to other hardware. Smart accessories are those more autonomous devices that connect to the network and that can perform some functions without the support of other devices. Finally, there are the smart wearables, or those devices that work in complete autonomy. They can autonomously connect to the Internet and have the ability to connect directly to the App with the aim of expanding their functionality, such as Google Glass.
3. Risk Society

Today a person, before leaving home, consults some application on his phone to check the weather conditions, and decide whether to take the car or not, or to simply choose what to wear. Before embarking on a trip, or to go to work, check the traffic map, to plan alternative routes that will ensure easier road conditions, or ensure you arrive on time.

The contemporary person, in moments of decision making with respect to the daily actions of living, needs tools that transmit safety, technologies useful to face the continuous risks that can be encountered. Seismic or hydrogeological risk; nuclear risk; banking risk; terrorist risk; road, railway, airplane accident risk; risk of ingestion, sunstroke, intoxication. Today the risk takes infinite forms, but no definitive definition.

Risk is characterized by its immateriality, it is a concept that manifests itself as invisible, imperceptible, and becomes real and tangible when it manifests itself and translates into effect. It is often represented by a number, a percentage, which defines the probability that an adverse event will occur. The uncertainty of person in front of the risk derives precisely from its unpredictable nature, not calculable, entrusted to probability. This induces today's society to an ever-increasing search for security, through the demand for guarantees, answers, reliability.

In 1986 the German sociologist Ulrich Beck wrote Risikogesellschaft - Auf dem weg in eine andere modern (Risk Society: Towards a New Modernity, 1992). In this book, he attributes this new definition to contemporary western society, the result of the same processes of modernization that determined its development. Although it was already present in some research at the end of the seventies, the attention to Risk Studies in the sociological field began with this book, until it became a fundamental field of research for the cultural interpretation of late modernity and not only in the social field.

According to Beck, the production of wealth generated by advances in science and technology, together with social, cultural and economic change, has led to an increase in risks. What has really changed is the relationship between individual and risk, his knowledge, his perception. Paradoxically, the conquest of well-being has produced a growing sense of insecurity and uncertainty, particularly about what is new, because it is unknown and therefore not governable. To the natural risk (earthquakes, floods, volcanic eruptions), traditionally attributed to chance, to a sort of fatality, during the second half of the 20th century technological risk was added, which is instead attributable to the development of industrial processes and therefore to humans. In some cases, the conscious choices of some people towards such risks have caused epochal tragedies.

Very well-known are the events related to the strong pollution from radioactive waste or toxic clouds, including those of Sellafield in 1957, Love Canal in 1976, Bopal in 1984 and Chernobyl in 1986.
Among the most relevant episodes, in the chemical and pharmaceutical industry, there are the cases of Thalidomide and Manimata. The first example describes the effects due to the spread of the drug Thalidomide among pregnant women in the period between 1958 and 1963, which caused serious damage and malformations in newborns, particularly in Germany; the second case concerns the methylmercury contamination of marine waters of a small Japanese centre, between 1956 and 1972, due to the spill of a chemical industry, which caused intoxications and serious neurological syndromes on its inhabitants.

To these are added health epidemics, such as Mad Cow of 1986, avian influenza of 2003, the current Corona Virus (2019).

People are always guilty of the spread of these phenomena and the damage they cause. These disasters have led to a deep crisis in civil society with regard to science and technology, particularly in relation to environmental and health damage. This new type of risk is no longer attributed to the unpredictability of nature. Political governance becomes the scapegoat, together with experts and scientists, for their inability to ensure the safety of their own communities.

The System of Risk Governance is in crisis, especially for issues related to the incommunicability between experts and laymen. The communication model adopted is in crisis, because it is linear and unidirectional, not attentive to the interpretative processes of the public that receives and interprets its messages.

The scientific community is beginning to realize that society has changed, it no longer has faith in political and/or academic institutions (Renn & Levine, 1991), its anxiety translates into activism, with the birth of environmentalist movements of revolt.

Risk can no longer be represented as something real and measurable, rational, defined by the evaluation of costs and benefits, and the statistical calculation of probabilities (Knight, 1921). With the growth of fear, insecurity, and the desire for knowledge in relation to risk, it is necessary to consider and evaluate other less objective conditions, which relate to psychology, culture, politics and ethics.

Risk Communication was born, an increasingly autonomous discipline, which bases its research on a multidisciplinary approach and the centrality of Human and Social Sciences (Kasperson & Stallen, 1991; Eppler & Aeschimann, 2008; Lundgren & McMakin, 2009; Sturloni, 2018). Risk Communication, in addition to defining coherent and effective communication strategies, is a useful and available tool for the community, to facilitate processes of participation, supporting open exchange and two-way and interactive dialogue. This paradigm shift in the communicative approach is even more necessary in the contemporary, chaotic and noisy context, characterized by the multiplicity of messages and the overlapping of channels, among which today the Social Media are also shown.

From a strictly communicative point of view, Risk Communication can be understood at the same time as a branch of scientific communication, public and institutional communication...
and social and public utility communication (Cerase, 2017). With each of them, Risk Communication can share the scope, or the objectives, or the approaches. In any case, its fundamental mission is to inform the people, allowing them to decide autonomously, especially in real risk situations.

Figure 1. Relations between different aspect of Communication and Risk Communication.

From the design point of view, in the project of risk communication, transversal skills are needed in different areas, from information design to interaction design, from co-design to service design. However, the decision-making tables of Risk Governance, although so largely multidisciplinary, rarely require these specific and highly qualified skills. Wrongly so, considering that communication activities always take the form of printed documents, websites and apps, maps and charts, diagrams and others data visualisations (Lickiss & Cumiskey, 2019).

Among these areas, information design can be fundamental in the construction of risk communication, as it deals with language (Jacobson, 1999). Operationally, it carries out two actions:

- translation, through the analysis of signs and language related to the cultural context of origin of the message and that of the final recipient, to add new levels of meaning;
- information, through the representation of messages (textual, graphic, numerical) in comprehensible visual forms, within structures consistent with the system that must decode them (Tufte, 1990).
4. Data and Risk

Among the little known and relatively recently acquired environmental risks is Radon gas. It is a natural gas, which comes from underground and is widespread in many countries. The risk associated with Radon gas is health-related, and derives from unintentional exposure to the radiation that the gas emits under certain conditions. Prolonged exposure to the gas can cause serious health damage and genetic repercussions. The World Health Organization claims that Radon gas is a substance carcinogenic to humans, and for The Italian Higher Institute of Health it is the second leading cause of lung cancer, after cigarette smoking. The European Atomic Energy Community has issued some directives (Directive 2013/59/Euratom) in which there are clear indications for the Member States of the European Community on how to take regulatory action, setting environmental limits, measurement and intervention procedures. Italy has accepted these directives with Legislative Decree n.230/1995 and with Radon National Plan for the reduction of lung cancer (CCM 23 May 2005), which refers to the individual regions for control, monitoring and verification procedures on the application of the rules. However, today not all Italian regions have yet adopted precautions, and in some cases the strategies undertaken are not exhaustive.

Once again there is a problem of communication. Between several levels. And there is a problem of priority order.

In the manner in which it is presented, environmental risk is interpreted as legislative risk in the event of non-compliance with the standard. It becomes more important to respect the law in order not to incur in judicial troubles than to understand the real extent of the risk to avoid damage to health.

Individual behaviour is the result of a choice, closely related to the understanding of a given phenomenon and the relative risk. It is not possible to direct towards good practices without targeted communication that is attentive to personal needs.

The Radon project – research project funded within the framework of the Regione Puglia Living Labs programme, with the European Regional Development Fund – was born on these premises, defining as a mission the construction of an active participatory system for raising awareness among communities of issues related to exposure to Radon (Amato et al., 2019). On the one hand, the project involved the development of an innovative product, based on ICT technologies, for Radon gas detection and alarm communication, to be placed in public and private buildings; on the other hand, the multi-level information of users, through products and specialized communication processes. In all project cases, specific interfaces were developed.

To implement these objectives, the project has put together a multidisciplinary team, aware of the need for an articulated system of specific and complementary skills: experts in technology, physics and biology, communication. This team actively collaborated with the
social base, through discussion panels, workshops and focus groups, according to a Human Centred Design approach.

The data at the heart of the communication process are manifold and complex.

There are measurements of the amount of radiation emitted, detected in real time through electronic sensors, which present a numerical data expressed in Bequerel. They depend on the environmental conditions and the material characteristics of the space. There are the values of radiation exposure, detected through personal dosimeters, which depend on the physical characteristics of the individual and the space in which the exposure takes place. They are expressed in milliSievert. There is the radiation exposure time, which depends on the physical presence of the individual in a given environment. There are georeferenced data (GIS) expressed by thematic maps, which collect environmental data of Radon gas concentrations over a larger territory (fig. 2). There are threshold levels, which set regulatory and health-related limits. And finally, there are the human variables, which concern the psychology of the individual and the culture of a social group.

![European map about Indoor radon concentration](https://remap.jrc.ec.europa.eu/Atlas.aspx#).

Sensors and other technological devices are able to collect all these data and process them through precision algorithms. In particular, an innovative personal dosimeter for ionising radiations, obtained using a multilevel approach based on Smartphones, artificial intelligence (AI) and data fusion, was developed for the Radon project (Scarcelli et al., 2020). The interfaces designed for communicating the risk of radon exposure translated the
complexity of scientific data into visual information, understandable by the non-expert user and useful for decision making (Fig. 3).

The design process was carried out in phases:

- research, through the analysis of requirements and needs during the discussion tables with the community;
- design, according to the methods of information design and risk communication;
- testing, with real users experimenting working physical prototypes and giving feedback.

These phases were repeated until the final prototyping of the interface, which was the common result and then shared collectively. Co-design with the end user ensured the validity of the device and the language adopted in the interface. The collaborative processes were also training moments, in which the complexity of the risk phenomena dissolved, reducing the level of uncertainty and insecurity.

Figure 3. Prototype interface for the smartphone application.

5. Conclusions

The development of digital technologies, the so-called smart and wearable technology, sensor technology, the study of network architectures and communication protocols in the IoT field, makes it possible to organize services and design products dedicated to user needs on the basis of a new virtual dynamic, human-data experience. This happens through the extrapolation of relevant statistics, suitably processed through the so-called Semantic Web of Things procedures, directly from the inputs coming from things worn, used, present in the environment (from clothing, footwear, work tools, machine interfaces, environmental
surfaces, etc.). These aspects open to new, methodological relevant ways of approaching design (advanced) that tend: on the one hand towards the development of a technical specialization, with implementation of technology, for "traditional" artifacts; on the other hand towards the birth of new cultural contexts able to define classes of new generation artifacts in response to emerging needs related with the new social challenge. Among these needs emerges a growing demand for security, determined by the spread of environmental and technological risks, characteristic of the so-called Risk Society.

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The Designer in the AI/Machine Learning Creation Process

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Abstract | Beyond the utopian and dystopian hype of artificial intelligence (AI) lies the sobering, narrow, pragmatic reality that is Machine Learning (ML). ML’s recent, highly publicized ethical failures have raised alarm at the bias that can creep-in through data, algorithms and design specifications, made even more problematic by ML’s aura of neutral rationality. Homogenous ML development teams described as a white male monoculture are now expected to practice ethics without specific training along with their computer science skills; however, moral philosophy is radically different to the abstract, computational thinking required for programming and optimizing code. Diversifying ML production teams (through gender, ethnicity, age, ability, etc.) has been proposed as a solution for this dilemma, but this approach is limited by systemic ICT (Information and Communication Technology) pipeline issues. One way to rapidly address lack of diversity in ICT is by bringing in other disciplines’ different value systems in the ML creation process. Larger companies can afford a larger, heterogenous team with social scientists, legal experts and ethicists joining their research and development teams; however, start-ups often begin with just a handful of data scientists and engineers, a lean structure made more perilous by the entrepreneurial catchphrase: “move fast and break things.” This is where the opportunity lies — to bring in designers into ML development teams — in a critical role that improves the ML creation process. User experience (UX) designers are trained to define stakeholder needs and goals, analyze situations and incorporate theories and methods from other disciplines like social science, engineering and management. UX designers that are trained in future/critical design, impact analysis, and system design are ideal candidates to diversify ML development teams, but first, UX methods for the specificities of ML production need to be established. This paper looks at an approach called MLUX (Machine Learning User Experience) design and proposes a two semester MLUX curriculum.

KEYWORDS | ARTIFICIAL INTELLIGENCE, DESIGN, UX, MACHINE LEARNING, MLUX, ETHICS
1. AI is a Wicked Problem

Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent systems that strive to work and react like humans. More hype than reality, AI falls under the definition of Richard Buchanan’s (1992) “wicked problems” that are ambiguous, difficult or impossible to solve. Arthur Samuel (1959) defined Machine Learning (ML) as giving “… computers the ability to learn without being explicitly programmed.” ML is an important subset of AI because intelligent behavior requires considerable knowledge, and ML is one way to acquire that knowledge. Neural networks in Deep Learning (DL) are a subset of Machine Learning. François Cholet (2020), engineer at Google and creator of the widely used Keras neural network library, best presents the conceptual misalignment of artificial intelligence with the cognitive automation achieved by machine learning:

“Our field isn't quite "artificial intelligence" -- it's "cognitive automation": the encoding and operationalization of human-generated abstractions/behaviors/skills. The "intelligence" label is a category error. Cognitive automation can happen via explicitly hard-coding human-generated rules (GOFAI), or via collecting a dense sampling of labeled inputs and training... a deep learning model. The second form is especially powerful, since encoding implicit abstractions only via labeled training examples is far more practical and versatile than explicitly programming abstractions by hand, for all kinds of historically difficult problems.

Cognitive automation is incredibly useful. But autonomous abstraction generation is a different creature altogether. As new lifeforms are to animated cartoon characters -- whether the cartoon character is modeled by hand or captured via examples. "If the cartoon is drawn with sufficient realism and covers sufficiently many scenes, what's the difference?", you may ask. Adaptability to the unknown. A lifeform will autonomously adapt to a changing future. An automaton will perform the scenes you planned for. Intelligence is adaption to unknown unknowns across an unknown range of tasks and domains. Automation is, at best, robustly handling known unknowns over known tasks (which is already incredibly difficult and resource-intensive in the real world -- whether engineering or data). The resource-intensiveness, naturally, comes from the lack of adaptability: you need to plan for every possible unknown, whether explicitly or via a dense sampling of possible situations (assuming a fixed distribution).” Cholet (07/01/2020)

ML models are created in a process that is more prosaic. An algorithm processes data in successive stages of quantitative transformations looking for features or patterns. This process creates a model that gets iterative refinements of the model’s parameters (weights) - by processing yet more data. The dataset quality is primordial. ML is not magic, just fastidious, energy-and-time-consuming calculations that gradually refine an ML model.

Teams of data scientists and engineers focus on this algorithmic pipeline, by cleaning and transforming the data and by avoiding traps of over-fitting or under-fitting the model to this data. These predictive ML models have trickled into our daily existence through
recommend systems on websites, personalized ads, financial and legal dealings, and more. Public trust — that these ML models were well executed and present an advantage over individual human bias — is a prominent concern for the industry (Hengstler & Als. 2016, Valor 2017, Floridi 2018, Winfield & Als 2018); however, public skepticism of AI seems well warranted.

ML’s spectacular ethical failures (O’Neil 2016, Wachter-Boettcher 2017, Broussard 2018, Eubanks 2018, Simonite 2018, Benjamin 2019, Zuboff 2019, Webb 2019) have raised alarm at the bias that can creep-in through data, algorithms and black box models, made even more problematic by AI technology’s aura of neutral benevolence and charisma (Robinette & Als. 2016). Government, think-tank and professional institutions have rushed in with ethical considerations and voluntary guidelines to help companies develop ethical AI (Jobin & Als. 2019); however, these recommendations have no legally binding obligations that could be construed as fostering an anti-innovation, anti-business environment. No legislative body wants to be accused of stifling innovation, leaving individual “losers” in ML systems with no other recourse than to seek legal action. With no institution setting the ground rules beyond the EU’s GDPR (General Data Protection Regulation 2016/679), conflictual matters get resolved in the slow gears of judicial systems years after the injurious “disruption” occurs.

2. Why Do We Need MLUX?

ICT (Information and Communication Technology) is a notoriously homogenous field which can be described as a white male monoculture. (Krupa 2018) Data scientists and engineers specializing in ML are often the products of highly selective schools and relatively privileged social classes. In other words, people making our AI are the least likely to suffer negative consequences from unfair or biased ML. Therefore, diversity in the ML development team is a crucial, but low hanging-fruit to bring competing visions, values and methods to a team, and hopefully foster a more sensitive consideration of ML’s social impact. Team diversity does need to reach around 30% for minority members to feel secure in expressing minority opinion and not be ineffectual tokens meant to check off diversity statistics (Krupa 2018).

Like entering the “magic circle” in a game, there is so much ML complexity to master and optimize that data scientists tend to focus on the algorithmic pipeline. Data is often considered the time-consuming, dull material that needs to get through the algorithm to tease out its true potential. Data scientist and engineers are not out to insert bias into their models, but they are not specifically trained to understand or detect it beyond statistical distribution. There is no discussion about hegemonic values inherent in categories like “gender” or “race,” or how social bias can enter the ML workflow.

In 2018, Yang & Als. looked at the practices of experienced User Experience (UX) designers in designing AI products and services and found that these designers expressed a heavy
reliance on data scientists without actually understanding the technology underpinning their designs. Data scientists serve as proxy for the designer’s technical expertise, leaving UX designers unable to anticipate and contest problems in biased, poor-quality data and algorithms and their repercussions on edge-cases in their stakeholder networks. In other words, by relinquishing their technical understanding to others, designers may perpetuate the disenfranchisement of minorities and the poor without even realizing it. UX designers’ over-reliance on data scientist’s technical understanding is a dangerous posture. Data scientists do not ensure and are not responsible for making sure that AI products and services are fair, accountable, ethical or trustworthy.

Certain AI Ethics workgroups recommend diversifying disciplines by inserting a “bias officer” on development teams. Large companies like the GAFAMs have their brand values at stake, serving as a deterrent to the most egregious abuses of public trust. They also have deeper pockets to support larger, more diversified teams. However, most start-ups begin quite lean, making the overhead of a social scientist/bias officer who cannot contribute to the ML algorithmic workflow economically unfeasible on a small team with two or three engineers. This is where the opportunity lies to bring in UX designers into the ML development team – in a critical role to improve the ML creation process by bringing stakeholder-centered needs and goals as a central value. UX designers are trained to define needs and goals, analyze situations and incorporate theories and methods from other disciplines like social science, engineering and management. (Preece & Als 2011, Hartson & Pyla 2012) They understand and can measure the impact of their interventions. UX designers can intervene on the initial data, looking not just for poor quality data, one of the most time-consuming tasks for data scientists, but looking for what data is under-and-over-represented. UX designers can also intervene on the understandability of the resulting models and predictions and on its interactions with human decision-makers. They are trained to incorporate big picture considerations like product lifecycles and social and environmental impact using speculative design methods such as design fiction and critical design. UX designers are pragmatists used to dealing with the constraints and limitations of a particular context, field or technology. In other words, an MLUX designer’s role is to be a ML generalist, to identify critical issues before final production or public product release.

Where can the MLUX designer fit into the ML development process?

- In defining the design brief for the project and all the stakeholders’ needs and goals (Amershi & Als 2019), keeping an eye on abusive end-user scenarios and problems that may arise from certain priorities and decisions in the initial Minimum Viable Product (MVP);
- In the intensive data gathering, analysis and cleaning process, ensuring appropriate distribution and quality in the final dataset, respecting the privacy and consent of data subjects;
The Designer in the AI/Machine Learning Creation Process

- In the development process, testing the accuracy, fairness and explainability (when possible) of its results; and
- In testing the resulting weighted model for its impact on edge-cases and the disenfranchised.

Each ML project has technical constraints requiring a basic level of technical ML competence to follow the development process and understand data processing and its extractive values. An MLUX designers is not in competition with data scientist or engineer but augments the team by keeping an eye on social impact of its decisions, enhancing understandability, fairness, accuracy and trustworthiness, and testing the results.

2.1. MLUX Speculative Design Methods

Designing evolving complex systems that may include non-human stakeholders (e.g. avatars, robots, and non-human living systems) may cause some UX designers to doubt the validity of their existing design methods. This increased systemic complexity has lead a number of design researchers and practitioners to propose new UX design approaches for AI and ML development. Van Allen (2017) proposes animistic design that moves away from human-centered design toward ecology-centered design. Bardzell & Als (2012, 2013, 2014), Malpass (2013), and Pilling & Als (2019) look at critical design and design fiction methods to explore both utopian and dystopian technological development and applications. A set of 18 design heuristics for human-AI interaction established through a user study of 49 design practitioners are proposed by Amershi & als (2019). Google’s People + AI Guidebook (PAIR 2019) aims to help UX designers and product managers bring a human-centered approach to AI development teams.

2.2. MLUX for Datasets

To complement the work of data scientists, new UX methods need to be developed to analyze the fairness and accuracy of datasets, particularly if it pertains to people. Some ethical issues that must be known about a dataset before its use in ML training:

- How was the dataset specified and financed?
- How was data gathered? Manually, through gradual accrual, aggregated from separate sources, or scraped for the web?
- Are dataset subjects known or willing participants? Is the data being used as it was originally intended?
- Who is over-or-under-represented in the data (against statistics and quantitative social science)? Should this be mitigated in the dataset? If so, using what techniques?
- What are the constraints or limitations on the dataset’s use?
Who labelled the data for supervised learning? How were they recruited, trained and remunerated?

An initial concrete proposition for accompanying ML datasets can be found in the proposal “Datasheets for Datasets” (Gebru & Al. 2018).

2.3. MLUX by Intuitive Analysis for Accuracy, Fairness and Explainability

After the data cleaning process, the algorithmic process requires digging down into its mathematical transformation: understanding how data gets interpreted, how values are extracted, how activation functions work, etc. This stage is often the most intimidating, fastidious part of ML mastery for non-programmers, but accomplishing this allows designers to play a useful role in the development process, testing the model’s progress based on how the models should be performing from an end-user’s point of view. This skill set development is the goal of the first year MLUX curriculum detailed in section 3.

To complement this approach, Google AI (Mitchell & Als 2019) proposes a framework, Models Cards, to describe trained machine learning models. Model cards are meant to encourage transparent model reporting through benchmarked evaluations across different cultural, demographic, or phenotypic groups (e.g., race, geographic location, sex, Fitzpatrick (1988) skin type) and intersectional groups (e.g., age and race, or sex and Fitzpatrick skin type).

2.4. MLUX for End-User Testing

Once a weighted model is created, MLUX designers can test end-users for explicity of the model, fairness for under-represented groups, validity of results for accuracy, and hopefully, a reduction of abhorrent results, especially if sensitive human issues have been identified. A terrible example of failing this step is Google’s Photo app that labelled African Americans as gorillas (Simonite 2018). Beyond the terrible MVP release, the image recognition problem proved so complex to resolve that Google Photo’s workaround was to simply remove the “gorilla,” “chimp,” “chimpanzee,” and “monkey” categories from its ML image recognition model. Other MLUX end-user testing techniques can be drawn from existing UX methods. (Preece & Als 2011, Hartson & Pyla 2012)

3. Proposition: Develop Core ML Competency and Understanding in an MLUX Curriculum for UX Designers

While programming is not be a core skill of MLUX design, basics programming concepts must be acquired to be able to reverse-engineer and discuss code with a development team. 42 (https://www.42.fr and http://www.42ai.fr) and the DIGITAL Design Lab (formerly Human
The Designer in the AI/Machine Learning Creation Process

Machine) (https://en.lecolededesign.com/research-design-labs/digital-design-lab/) work primarily in Python and its common ML packages like Numpy, Pandas, Keras, Tensorflow, Sci-Kit Learn, and create workflows in Jupyter Notebook or Google Colaboratory. While user-friendly options like RunwayML may be easier to master, using pre-existing black-box ML is to be avoided. This reverse-engineering component differs from existing MLUX curricular approaches that develop primarily theoretical and ethical approaches to ML understanding.

3.1 MLUX Origins: Michelle Carney and the Stanford d.School

Stanford University’s d.School (https://dschool.stanford.edu) has implemented a MLUX course since 2018 created and taught by Michelle Carney, computational neuroscientist and senior UX researcher at Google AI. Entitled “Designing Machine Learning: A Multidisciplinary Approach,” the d.School curriculum’s first iteration was an 8 week ML theory course (Carney 2018), followed up by a 10-week theoretical curriculum proposed this year (Carney 2019). Michelle Carney’s MLUX curriculum serves an as influence to Digital Design’s 5th year MLUX curriculum presented in section 3.3, and we are grateful for her highly-engaged, open-source approach to MLUX best practices.

3.2 MLUX 1st Year MA Curriculum

In addition to acquiring programming knowledge, MLUX designers needs to learn key ML and Deep Learning (DL) concepts, methods, applications, workflows and approaches — stressing pragmatic and conceptual understanding of feature extraction and developing intuition for the development process. Based on 42’s 14 week ML curriculum, MLUX students are introduced to supervised, unsupervised and reinforcement learning algorithms using practice-based reverse-engineering that gradually increases in complexity.

1. Intro to ML + Python;
2. Simple Linear Regression + Linear Algebra + Numpy;
3. Multiple Linear Regression + Derivatives/Gradient + Pandas;
4. Logistic Regression;
5. Support Vector Machines;
6. Decision Trees + Random Forest + Boosted Tree;
7. Naive Bayes;
8. Unsupervised (PCA & K-Means);
9. Recommend Systems;
10. Neural Networks (Intro);
11. Convolutional Neural Networks (CNN);
12. Recurrent Neural Networks (RNN);
13. Reinforcement Learning + Q-learning;
This sequence has the benefit of gradually building on acquired skills and allows the designer to develop autodidactic methods for learning new ML algorithms.

3.3 MLUX 2nd Year MA Curriculum

Once a technical understanding of the ML workflow is acquired, the second year focuses on ML’s theoretical and ethical underpinnings and its link to UX design practice, through scientific literature, creative coding exercises and reflexive thinking.

1. Data Collection and Data Science Workflows;
2. Data Visualization and Exploration;
3. Recommender Systems and UX;
4. Natural Language Processing and Voice Interfaces (Chatbots and VUI);
5. Computer Vision (Neural Networks and High Dimensional Classifiers);
6. Image & Video Processing, Transfer Learning;
7. Generative Design & GANs;
8. Disruption, Innovation, Ethics and Bias.

The second year has fewer sessions with increased time spans to allow more creative student exploration.

4. Conclusion: MLUX for Ethical AI

In conclusion, the most useful role for a UX designer on a ML development team is as a reality-check when the charisma of numbers proves too intoxicating. UX designers that develop critical and speculative design skills learn to imagine both benevolent and malevolent appropriations of technology. Understanding a technology’s simultaneous potential and danger is a UX designer’s most useful discipline-diversity contribution — fostering a more context-sensitive approach to ML research and development. The MLUX designer ideally steers the development team onto the right path.

Design adage: simply because one can does not mean one should.

References


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Dr. Frédérique Krupa is director of the DIGITAL design lab at the école de design Nantes Atlantique. Her research focuses on establishing ML UX design methods, a holistic, transdisciplinary and systemic approach to create ethical machine learning datasets, predictive models and applications.
The encounter between Design and Artificial Intelligence: how do we frame new approaches?

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Abstract | Artificial Intelligence is promising to change people’s lives, either by replacing human activities or by augmenting human capacities. Affecting society, AI will also help rethink notions and characteristics of what we design; however, as developments have just begun, potentialities and risks are not straightforward: what will the characteristics and logic of design be in an era in which learning systems will be the centre of attention?

The paper frames this question offering a critical discussion about the role and logic of design when AI is “the material” of the project. It explores the issue drawing on AI-Cities, an initiative that has designed digital services applying AI in three public administrations. The paper proposes two main changes: the need to design constantly evolving, ill-defined interactive systems both in terms of problem and solution with AI as one of the users; the need for undisciplined design approaches to develop AI-based design objects.

KEYWORDS | DESIGN, ARTIFICIAL INTELLIGENCE, HUMAN-CENTRED APPROACH, DIGITAL SERVICES, UNDISCIPLINARITY
1. Introduction

Artificial Intelligence (AI) is promising to considerably change people’s lives, by replacing or augmenting human capacities in tasks as varied as safety management and diseases diagnosis. It is also transforming the notion of machine, from static problem solver to creative generator of other machines and future decision maker of what people will like, wish, consume, think. This is also changing the way people interact with each other and with machines, as these last are envisaged to begin to think and learn by themselves. In both public and private sectors, the spectre of applications is already wide and encompasses city dashboards, chatbots, smart advertising systems, intelligent driving vehicles, equipment for human-machine collaborative surgeries, and many more. Beyond this, what organisations seem to be valuing is also the data collected on human behaviours and wishes, that is then used and analysed through algorithms of intelligent data processing as well as other predictive technologies to design and propose new offerings (Zuboff, 2018).

These applications can be at the same time exciting and frightening: how much will life be determined by algorithmic predictions of actions and emotions? Will humans be able to use AI to augment their own intelligence and perimeter machine learning into a tool to handle increasingly complex tasks and larger amounts of data? Whether answers will be optimistic or not, AI will undoubtedly help rethink the current notions of what we design, including products, services, interactions, experiences, systems and organizations. However, as the new hype around AI has only begun to emerge and its impacts on society are still unknown, potentialities and risks are not straightforward. Consequently, at present we need to engage in as much discussion and reflection as possible to develop a critical approach to designing AI for the present and the future.

Here, design is asked to modify its logics and complement competences if it wants to remain relevant in this discourse: on the one hand, some continue to propose an ethical and fair design mainly used to advocate for the people (Margolin & Margolin, 2002; Manzini, 2015); on the other, some are exploring the shift in the competences and logic of design to become a full part of the new market of human behaviours (especially big corporations are working on this perspective, rather than individual experts).

Building on this, the future of design seems to pose new questions, that is, what will the characteristics and logics of design be in an era in which learning systems will be the centre of attention?

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1 Examples include the work developed by Google (https://ai.google/) and Microsoft (https://www.microsoft.com/en-us/ai?activetab=pivot1%3aprimaryr5), that for instance have established not only specific teams to investigate the development of the topic, but also created ecosystems of start-ups, universities and researchers (https://openlearning.mit.edu/news/met-microsoft-and-mit-explore-impact-artificial-intelligence-how-global-audiences-connect-art) that are helping these big corporations evolve their knowledge as fast as possible.
This question opens new avenues of reflection, referring both at how the process of design could be modified integrating new tools to frame the needs of people, and at the outcomes of this process when new technologies are used in the final solution. When design meets AI, we must consider a double-sided perspective: AI as a tool in the design process, AI as material to be shaped into design projects.

If the first perspective is less explored, the second is already receiving attention especially from big corporations (e.g. Google, Microsoft, etc.). In this paper, we will focus on this second perspective, leaving the other part of the discourse opened for future reflections. Specifically, the paper aims at offering a critical discussion about the meeting between Design and AI when the second is “the material” of the project. It explores the issue describing a specific case in which AI has been designed in new digital services within three European municipalities (Bologna, Strasbourg, Tallinn). In particular, it draws on an initiative called AI-Cities, that has envisioned AI through the blended use of interaction and service design, where the first (interaction) was used to understand how the integration of disruptive technologies is changing the relationships and interactions between citizens, government and services; the second (service) focused on the best tools to guarantee wide participation in the creative process and understand workflows for the meaningful integration of technology. This integrated approach could offer a new mindset to the design and adoption of disruptive technologies; however, it is not immune by criticalities and limitations. In particular, we discuss two aspects:

- The relationship between AI-based experiences and users, and their design – how to design constantly evolving, ill-defined interactive systems?

- The need for undisciplined design approaches (Bremner and Rodgers, 2013) rather than inter-disciplinary ones, to respond to the complexity of new AI-based design objects – how should diverse design disciplines merge to meet this challenge?

The paper is organized as follow: first, it gives a brief overview of the relationship between AI and design; then, it describes the AI-Cities project, the method used in the project and its results; finally, it offers a critical discussion about the topic, declares the limits of the research presented and underlines potential avenues for further research.
2. Design and Artificial Intelligence

Today’s technological progress has extended the capabilities of humans and has begun modifying activities and daily tasks: indeed, novel technological applications in fields like ICT, biotechnology and AI are promising to give life to unexpected possibilities. Focusing on AI, this is already applied to automate many tasks that had previously been regarded as impossible or impractical for machines to perform. For instance, computers and applications can now diagnose disease, create digital humans to perform realistically, or help people with disabilities perform tasks and be more independent (i.e., the application “Seeing AI” from Microsoft transforms the smart phone into a device capable of scanning the environment for identifying other people or finding specific objects).

Although exciting, this progress poses many questions linked for example to understanding how people should approach (cognitively and emotionally) the massive change envisioned, where machines will begin to think and learn by themselves. For scholars and experts, the answer is controversial. For instance, according to Stephen Hawking “the development of full artificial intelligence could spell the end of the human race.” Elon Musk, the CEO of Tesla Motors, also noted in Twitter in August 2014, that “we must pay the closest attention to AI because it would bear more danger than nuclear weapons.” As opposite, Wired released in 2019 a documentary film on AI and machine learning examining the applications and potential impacts of AI, underlining its great potential to change human life for the better. In the movie, Nicholas Thompson, Editor in Chief at Wired states: “My instinct is that AI is going to help us: it will expand our capabilities, it will create new things for us to do, it will free up time (...) the most important task for AI to accomplish in the next 8-10 years is to free up humanity from repetitive work”. Additionally, Kai-Fu Lee author of “AI superpowers” states: “a lot of the dystopia, doom-talking, is not really based on facts. People are looking at things they don’t understand.”

Scholars advocate for different scenarios, too. Makridakis (2017) explores four possibilities regarding the role that humans will have in the development of AI: the optimist, the pessimist, the pragmatist, the doubter. In the first case, a utopian future is foreseen where Genetics, Nanotechnology and Robotics will allow humans to harness computer capabilities directly into their brains; in the second case, humans become an endangered species as machines will grow to control everything; the third scenario believes that AI will complement and expand human capabilities for the benefit of everyone; the fourth one does not believe that AI is possible at all, and therefore it will never become a threat to humanity.

As discipline concerned with the artificial man-made world (Simon, 1969), design will also undergo changes following the progressive integration of AI in the society, and according both to the new nature of objects, and the resulting human behaviours.

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2 The full documentary can be watched at: https://www.youtube.com/watch?v=ZjixNvx9BAc
Intriguingly, design (both as discipline and practice) will be concerned with and affected by the majority of changes that AI will bring. Google has begun exploring this issue talking about human-centred AI, and essentially working on developing tactics that designers can use to mould AI as if this was a new material\(^3\). As proposed by Google, the core in the activity of designers remains the understanding of users’ needs and their translation into meaningful experiences, while AI becomes the medium that can help answer needs revolutionizing experiences and creating new relationships between customer and product. In this case, the novelty that designers will need to learn to deal with is the possibility of never-ending modifications and improvements that AI-based experiences promise: just like algorithms keep learning, so the system will continue to evolve; accordingly, designers will need to deal not only with ill-defined problems but also with ill-defined systems and experiences. The designed interactions will thus be just the beginning of the ongoing conversation between a system and its users, where intelligent products and services might change overtime according to feedback and circumstances.

How can designers deal with this new layer of uncertainty? Which scenario (the optimist, the pessimist, the pragmatist, the doubter) should we embrace? What tactics and competences can designers use? How can a new approach be framed to deal with this new “design material”?

According to Bremner and Rogers (2013) design is undergoing a transformation: due to global financialization and the rapid adoption of digital technologies, the models of design thought and action have been modified, superseding the historic disciplines. Building on this, the authors suggest the need to move from “a convention domesticated by practice to a responsive reformulation of practices” where the boundaries of design disciplines are blurred and reconfigured according to needs. They call this *undisciplined design*, “an ability to mash together jumbled ideas and methods from a number of different, distinct disciplinary practices that can be brought together to create new unexpected ways of working and new projects” (p.12). Other scholars have also discussed the blurring of the boundaries of design disciplines. Rodgers and Smyth in 2010 edited a book called *Digital blur*, describing how the practice of design modified by the digital world cannot fit into orderly categories, but should rather be seen as a hybrid of art, engineer, design, entrepreneurship, anthropology. In 2008, also the Design Research Society had identified this issue and underlined a discussion about challenging existing design specialisms. Finally, Blackwell (2008) distinguished design from other disciplines because the second are recognised for their rigour in addressing well-formulated problems through agreed methods of inquiry, while design mainly builds on subjective intuitions; he thus acknowledged design as *undisciplined*, identifying a more radical approach to creating and circulating knowledge

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\(^3\) Google has developed the “People + AI Guidebook” (https://pair.withgoogle.com/) for designers dealing with AI, and published interviews to explore the topic (i.e., https://design.google/library/ai-design-roundtable-discussion/).
The encounter between AI and design strongly reconnects to this discourse: once again design practice and research will need to be *undisciplined* to be able to deal with uncertainty in problem and solution. Building on these premises, the AI-Cities initiative (hereafter described and discussed) explores the introduction of AI as *design material* shaped in digital services, by means of a blurred (or undisciplined) design approach.

### 3. The project: AI-Cities

*AI-Cities* is a collaborative effort lead by Politecnico di Milano, where three cities (Bologna, Strasbourg and Tallinn) have been consulted to co-design and envision the introduction of AI in one of their services to make them digital and intelligent. In the next paragraphs, we describe the activities developed and the main learnings emerged from the project.

#### 3.1 Method

*AI-Cities* has involved three municipalities to help them proceed in their path toward Digital Government (OECD, 2016) through envisioning the adoption of AI in one of their services. The approach has been designed around a ladder useful to map and frame local strategies according to three steps: (i) **Digitization**: public services are government-centred and users are passive receivers of digitally delivered information; (ii) **E-government**: public services are citizen-centred and users can participate in service delivery through digital channels; (iii) **Digital government**: public services are people-driven and thanks to digital tools, users can voice their demands and needs, contribute to shaping political priorities and public services. This ladder has been the starting point to set individual goals of each local project: Bologna was assigned the goal to reach step 1, because it had only recently launched digital transformation initiatives; the Eurometropolis of Strasbourg was considered suitable for the second step, as the city started experimenting on digitization in 2013 with initiatives related to open data and health services and in 2018 established the citizen digital platform for public consultation. Finally, Tallinn in Estonia represents the so-called digital republic (it already launched several digital services starting from 2008), thus meeting the objectives of the third step.

After setting goals, the cities were engaged in a process of co-design to identify the most suited inclusion of AI for their local priorities and interests, thus choosing to integrate algorithms on different types of public services in each site. Virtual co-design sessions were run to identify and explore city problems and priorities, share documentation and ambitions, map internal processes and understand digital literacy, imagine together the potentialities of the technology and check the existence of appropriate databases and datasets useful to run the future experimentation. More in details, three sessions were run with each city: the first
to collect the starting evidences on the local initiatives dedicated to digital transformation, involving mainly design experts and Chief Technology Officer locally; the second and third have been larger sessions that have involved a higher mix of profiles and experts (designers, city managers and civil servants from different departments, AI experts) to first identify the service/policy area in which the experimentation could take place thus sharing related existing data and people’s needs, to then envision together the potential implementation of the technology.

3.2 Results: Using AI as material for digital services in local government

The digital services envisioned are hereafter described.

The Metropolitan city of Bologna – working on digitization for information acquisition – decided to use AI in a service aimed at efficiency and data management. Bologna decided to support the local increase of employment, by matching people seeking jobs to the most appropriate job offer using and integrating a range of current services.

The Eurometropolis of Strasbourg – working on e-government for decision making – focused on the application of AI to improve the interaction between government and population. Strasbourg decided to work on mobility and health as policy areas to test AI as knowledge organizer and advisor; the algorithm in this case is envisioned to receive and process citizens’ inputs, prioritizing them, advising civil servants on wished changes and learning about citizens’ priorities on diverse topics.

Tallinn municipality – working on digital government through co-design – focused on the use of AI for the co-creation of public value. Tallinn decided to experiment the introduction of machine learning (jointly with virtual reality) in the process of public deliberation and test it as aid to public decision making for ranking and sorting suggestions coming from the citizens.

4. Analysis and Discussion

The AI-Cities initiative – despite remaining an exercise of concept development – helped raise several considerations about constraints and role of design when working with AI, challenging our perspective as researchers and experts that could be summarised as follows:

- The need to design constantly evolving, ill-defined interactive systems both in terms of problem and solution, with AI as one of the users acting in the system;
- The need for undisciplined design approaches (Bremner and Rodgers, 2013) to respond to the complexity of AI-based experiences.
AI-based experiences are alive; they are not static but evolve over time because the system learns from each new data captured. This – from an engineering point of view – means that the system becomes sharper and less fallible; from a design point of view, it makes AI one of the active users of the system. As such, AI needs to be treated like any person during the design process, that is, an actor with evolving characteristics and needs. These encompass not only technical needs, for example concerned with maintenance, but also needs linked to growth and expansion of capabilities, that could lead to new applications and unexpected modifications. Building on this – beyond the ethical implications that this might bare (i.e., are AI systems living things? If so, of what kind?) – AI-based experiences should be considered as completely new types of design objects needing a blend of diverse approaches to be devised and preferring those already accustomed with relationships and interactions.

In our short field experience, we experimented the blend of service and interaction design, both traditionally dealing with mixed (tangible and intangible) systems that evolve overtime, based on the relationships and knowledge created between the actors and objects involved.

In our approach, service design was central to give users the right tools to participate in the creative process while providing infrastructures to facilitate dialogue, inclusion, and transparency. This was especially useful in the initial part of the process, when user needs (including system’s needs) had to be identified, aligned with AI potentialities, and translated into sets of data to feed the technology. Here, service design provided tools to analyse workflows, methods to find opportunities for AI and identify potential scenarios of use. AI currently offers to automate or augment human capacities; therefore, it is crucial to understand where in the process this can meaningfully happen according to local situations. Here, questions to drive the process could be: is the task something that humans really enjoy doing? Or is it something repetitive and boring, and at the same time standardised, thus transferable to a machine? Furthermore, when translating user needs into datasets important design tasks are connected to labelling data (together with the quality and representativeness of the dataset itself) as this could easily lead to biased algorithms.

Interaction design was central in the experimentation to understand how the integration of AI is changing the relationships and interactions between people, artefacts, environments and systems, thus defining new behaviours for both (Forlizzi et al., 2004). When dealing with AI-based experiences for example, an important step in the design process is about working on the mental models of end users to help them build the right expectations and trust for AI. Mental models, intended as a person’s understanding of how something works, play an

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4 Examples provided in the Google “People + AI Guidebook” include: Representational harm, when a system amplifies or reflects negative stereotypes about particular groups; Opportunity denial, when systems make predictions and decisions that have real-life consequences and lasting impacts on individuals’ access to opportunities, resources, and overall quality of life; Disproportionate product failure, when a product doesn’t work or gives skewed outputs more frequently for certain groups of users; Harm by disadvantage, when a system infers disadvantageous associations between certain demographic characteristics and user behaviors or interests (source: https://pair.withgoogle.com/chapter/data-collection/).
important role here, because of the need to prepare the user to co-learn together with the system as both evolve together. Feedback and co-learning are thus important elements to manage, going further than responsive products: AI not only receives and adapts response according to feedback, but learns from the experience, meaning that it develops new knowledge and ways of understanding an issue to expand its own features. Furthermore, mental models need to be built also for the AI component that should learn how to adjust to user feedback, interpreting all kinds of feedback received.

These insights show the importance of breaking the silos in individual disciplinary viewpoints. Our experience showed that none of the two disciplinary approaches involved could comprehensively cover all aspects needed, leading us to advocate for the importance of using a blurred approach that could also be described as undisciplined. According to John Marshall and Julian Bleecker (2010), undisciplinarity is both a way of doing work and a departure from ways of doing work. It is a process for creating knowledge that doesn’t need to worry about the traditional silos established by disciplines, but it can go middle ways to create new understanding altogether. That is why it is called undisciplined; as such, it appropriately represents what design is called upon to do when considering AI as a new material or even a new user in a project.

5. Concluding Remarks

Nicholas Thompson, Editor in Chief at Wired states: “we are building this incredible technology (machine learning, AI) and we are setting rules for it right now, and one of the big questions, one of the most important questions is: will we set the rules right? AI will have all kinds of massive benefits, it will make us richer, it will make our lives broader, but it can also be used to create filter bubbles that will only give us certain information, it can be used to monitor our behaviour, sell our personal information (...) a lot of the stuff that is happening now, we need to think carefully about to understand how we develop this technology and figure the role we want AI to play in society”. This includes also reflecting upon and discussing the role of design in the application of this technology, and this discourse is especially central now that design has reached a mature inclusion in many industries. In this paper, we have tried to offer initial points for discussion on this topic, mainly linked to designing with AI, and providing learnings coming from our direct experience. Based on this, we have highlighted the main points in which including AI is making a difference for design, thus proposing two main topics: the need to design ill-defined solutions as well as for ill-defined problems, where the system is itself a learning actor; the need to adopt a blurred design approach, where competences coming from different disciplines can merge and evolve outside of the traditional disciplinary boundaries.

Furthermore, we have proposed few specific moments and tools coming from service and interaction design that could be matched in a more comprehensive approach to
designing with AI. This undisciplined approach – if developed further – could offer a new mindset to application and adoption of disruptive technologies more in general, that should find broader arenas for experimentation and discussion in the design community to be fully developed. Further developments are also needed to verify the characteristics and logics of design for AI proposed in the paper, that should only be considered initial rather than exhaustive.

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The encounter between Design and Artificial Intelligence: how do we frame new approaches?


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The Perceptual and Dialogical Form of Design between Time, Space and Technologies.

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Abstract | In a continuously evolving society, where time, space and technologies meet, the individual is no longer satisfied with preconfigured routes, traditional models of knowledge transfer are no longer sufficient and there is an increasing necessity for developing new ones. The advent of technologies and the evolution of the relationship between Design and Cultural assets have called attention to the possibility of personalizing fruition. The person transforms from simple user/consumer into an active participant in creative processes for knowledge acquisition and production. In this context, also the learning and culture dissemination process needs to undertake new forms, from passive to interactive, making use of contemporary tools and techniques. Therefore, architecture and design have a decisive role in the way information is received, starting from the morphology of the space where the individual finds himself while connecting with knowledge, until designing the smallest details of the systems used for its transfer.

KEYWORDS | HIGH TECHNOLOGY, SPACE INTERACTION, PERCEPTUAL DESIGN, CULTURAL PLACES, MULTISENSORIAL EXPERIENCE
1. The hyper-connected society between progress and denial

We live in a world of contradictions, where progress is beginning to induce fear and eagerness at the same time. We do not know yet how to deal with the entire amount of information “attacking” from all directions with a velocity that not long ago was even hard to imagine. A query that has been tormenting scientists in a while now is how to keep all this knowledge from getting lost. In a society constantly evolving towards the digital world, the changes regarding the relationship between human beings and memory are stirring scientists and designers to further study and research.

We are not yet able to completely understand what technologies can offer. Thus, we often behave as children in front of a new toy: the enthusiasm of the discovery gets contrasted by the fear of getting hurt. Any transformation comes as an outcome of a crisis, when traditional concepts turn out to be obsolescent and they are limited to responding cultural, social and economic dynamics. At this point, the awareness of how only design culture can establish a new meaningful equilibrium and imagine more appropriate scenarios for the current transformations, comes along (Irace, 2013, p.7). This is the real challenge: how to bring innovation in a field that is under continuous change.

We think we know so much since we find ourselves in front of an infinite amount of information, but we do not know anymore how to record all this, how to put it inside our human “hard disks”, so we use the artificial ones instead. Where does all this knowledge go? Is this how it’s supposed to be? Technologies should be a support for the developing society and should not block human development in order to make space to the machines. We need to face this challenge in order to be able to conserve the positive parts and therefore we must count on interaction.

Interaction is a concept that has always existed, but it did not receive the proper relevance, maybe until we understood that machines can completely modify the persons’ approach towards one another and towards the surrounding environment (Mancini, 2013, p.28). This is a critical aspect, since everything gets modified: from the simple “intrusion” of smartphones into our lives to the connections inside the city and to the way we manage to acquire information. Human nature is defined by interaction and technologies can help people to interact with the surrounding environment in ways that were not possible before.

How can we enjoy the great advantages of an era where technology seems to enable an evolution without precedents? Maybe we are, in the end, too “little” to face this progress. Or maybe not. One thing is certain: we need to do everything we can in order to keep up with this evolution. We need to face this “technoliquidity” (Cantelmi, 2013, p.7) with the appropriate tools and to transform it into “matter” or, better said, into something that “matters”. Design and culture, put together, enable us to at least dare thinking forward, to imagine a future, not that far, when progress will not be feared anymore, because we will have gotten equipped with the necessary tools to deal with it.
The necessity of thinking and designing new ways of interaction with cultural heritage, considering its different connotations as tangible and intangible cultural heritage, leads us to new models of enjoyment. These imply a strong component linked to the experiential factor, to memory, to the “dynamics of return”, to the possibility to explore and reach different levels of knowledge of the asset, be it a work of art, an architectural piece, or a complex system such as a city or even a territory with a perimeter that is more difficult to read and define.

“There is a development of a new way to design and understand the contemporary artefact: not only just physical, neither just intangible nor digital, but a hybrid of these two components of the contemporaneous. Sometimes it becomes very complex to properly distinguish subject and object in the cognitive process.” (freely translated from Greco, 2019, p.16)

Cultural heritage has a fundamental role in producing positive stimuli, however new “metalanguages” must be found in order to provide it with the potential to transform “non-places” in “new places”. From interactive learning environments to immersive systems or augmented reality, these are all intents of knowledge dissemination for all, in a society where time is always “less”.

Technologies become an instrument that can favour the entire process, but they risk staying part of an “other” reality if their potential is not used in order to highlight the capacity to satisfy the continuously updating human needs. However, technologies do not have to be used in order to tell a story, to narrate art or culture. These should instead be interpreted with the support of technology. It is only then that the visitor will really be attracted by the meaning and the message that he could learn.

“The machines have introduced the possibility to delegate the recording of information, maybe by underestimating the transformations that these processes produce for the human body, therefore modifying the dynamics regarding individual and collective memory. Consequently, in the future, designers will reshape the relationships between human being and artefact at various scales.

On the contrary to what one might expect, there is a risk that this permanent connection and the massive amount of information could in fact result in “non-communication”, because often these connections do not create individual or collective memory and there seems to be a lack of identity. Under continuous movement, information becomes flat, without assuming real value for the human being, therefore generating only “excessive background noise” (Zannoni, 2018, p.17).
2. Dematerializing space between imagination and perception

Space also gets transformed and new configurations are being researched in order to satisfy the person’s continuously transforming needs. “In this always connect dimension, designers must have a critical approach to find solutions and organize spaces that go beyond physicality and become the appendix of a bigger system” (Zannoni, 2018, p.18). As proved by Ulrich Kirk from University College London, the aesthetical judgment depends on the context (Kirk, 2008, p.6).

Interaction with the architectural space and its impact on the human experience becomes therefore of fundamental importance. How should we deal with this? There are numerous facets of the problem and, at least until now, no universal solution, but maybe this is in fact the main mistake: we tend to universalize everything, we want global solutions, but we tend to forget that each person is different from another one. The themes of customization and inclusion belong to the present and to the future. Experience can be improved by considering the individual necessities as much as possible and by trying to satisfy them with the means at our disposal (which are multiple).

Lev Vygotsky (1896 – 1934) highlights the fundamental importance of social interaction for the construction of personal meanings out of experiences. Through the “Zone of Proximal Development”, he explains that there are understanding capacities and skills that go beyond the individual and that he can reach due to the social support and interaction. For Vygotsky, language, which is fundamental in the cognitive development, is considered a medium through which the individual can represent the experiences and the concepts to himself and to others (Lehnes & Carter, 2016, p.8).

Once the space abandons its abstract dimension and gets related to time, contacting reality, it becomes a place. The reality of a place is represented by the human being that inhabits it, that fills it with memory and determines its temporality (Branzi & Chalmers, 2007). Architecture cannot exist without a human dimension, as an object totally emarginated from the context.

The position inside space and time, together with the chosen perspective, determine the way how reality is perceived, a perception that is actually different for each person, even though it takes place in identical conditions. On the other side, empathy development can depend on transposing into a different spatial-temporal condition. Despite all this, an object which is more or less “steady”, meaning that does not suffer sudden or rapid changes, as in the case of cultural heritage, will be perceived similarly by various persons. The interpretation of cultural heritage creates links between the imagination and perception of reality through direct experimentation of a site or an object belonging to the past, thus increasing imagination and empathy (Lehnes & Carter, 2016, p.26).

In his studies, Lefebvre identifies three elements for the definition of space: the physical, natural one, the mental one and the combination of the two, which results in the social space (Lefebvre, 1991, p.11). Nowadays however, technologies interfere with these
dimensions, since they can “reduce the individual’s sense of presence within the space that he occupies” (Barra, 2019). Nowadays we cannot think from just one perspective, but we need to combine instead multiple views in order to better understand the context.

The eye of the machine produces a look that is also a space, overlapped and hybridised with the real one and determining therefore two perspectives regarding the computational sight, one related to the environment and the other to the user experience. Referring to the environment, there is an augmented space derived from augmented reality and understood as a result of various actions that enable to fill the physical space with levels of data (Arcagni, 2018).

“Another fundamental aspect is to understand how all these technologies act, not only by creating magnificent visualizations of collections but also by giving rise to new observing subjects within us.” (freely translated from Geismar, 2019, p.24)

A holistic approach could be a solution, even though proper experimentations must still be done. The neurosciences have achieved a role in design in order to find solutions for various problems of the contemporary society. Design uses neurosciences and neurosciences use design to prove how people can be brought closer to the project and how can interaction affect the overall experience.

We are dealing with a complex neuronal network for spatial encoding, situated inside the hippocampus and composed by various types of cells, such as: “place cells”, “grid cells”, “head direction cells”, “border cells”, which contribute together to the perception of space and to the construction of the so-called cognitive maps. The discovery of the “place cells” has in fact brought to awarding the Nobel Prize in 2014 to the scientists O’Keefe and the Mosers, for finding “a positioning system in the brain” (Grieves & Jeffery, 2017). Research continues to find out how can brain cells contribute to the cognitive representation of space and their connection with memory processes.

Specifically referring to art and aesthetics, neurosciences deal both with the study of the experience components, and with understanding the visitor’s aesthetic preferences, the subjective perception of beauty. On one side, the rational component is studied, while on the other one, the emotional dimension is investigated to discover any universal rules for the perception of beauty (Ovadia, 2019, p.25).

Therefore, multisensoriality becomes fundamental, even more when considering that the neuroscientific studies have proved how any experience of the environment is not only perceived through one of the senses, but through their combination. This kind of cultural experience will be able to get the brain involved and will determine major levels of empathy and understanding of the artefacts in times and spaces different from ours (Axel & Feldman in Levent & Pascual-Leone, 2014, p.353).
According to Changeux, from a cognitive perspective, both the artistic contemplation and creation can be considered subjective, conscious experiences that give access to conscience. Theoretical models and objective measurements, such as the ones using brain imaging, have been used to study the complex mechanisms of this kind of experiences, which can be considered an endogenous process contributing to the access of both internal and external information through a distributed network of neurons. The artistic experience can therefore be considered a conscious and unique synthesis of external perceptions, internal memories and archived emotions that gives birth to emotions in harmony with reason (Ovadia, 2019, p.27).

Nowadays, the connections and complex ramifications developed between people, objects, buildings and cities bring about the synapses that ensure the continuity of the nervous stimuli (Zannoni, 2018, p.16). There is a neurological characteristic named “mirror-touch synaesthesia” that enables the person to feel empathy while observing the touch of another person or object (Martin, 2017).

Regarding the sensorial perception and the “other” interaction with the work of art, the immersive experimentation “Tate Sensorium” (Figure 1) has been made in 2015. The capacity of the person to interact and observe through senses different from the sight has been explored, while as well enabling the recording through technological tools. Thus, memory and imagination have been stimulated (Tate London, 2020).
The perception of their own presence and influence, transmitted through the humans’ contribution to the creation of art, can also bring changes in the daily behaviour. This is the theme that inspired the Dutch designer Daan Roosegaarde for the realisation of the Presence exhibit at the Groninger museum in 2019 (Figure 2). The visitors are encouraged to do various actions inside the space, by leaving footprints for the ones that follow. Oriented towards the sustainable development topic, the designer manages to increase awareness of own presence by stimulating the senses through touch, movement and by playing with colours and textures. Direct interaction with our “traces” contributes decisively to a major cognition (Aouf, 2019a).

3. Expanding the technological dialogue into the polysensory dimension of design

In this dense network of virtual connections, where machines increasingly replace the individual in the performance of various activities, a fundamental question emerges: what is the relationship between the new technologies and the human body? These technologies assume the form of objects, clothes, prostheses, fabrics, surfaces, interfaces, in a process of contiguity and hybridization with the body itself, which strongly affects the definition of each person’s identity.
A mask, a garment, a disguise, cosmetic surgery, artificial skin, interface, are all various applications of the same phenomenon, fascinating and terrifying at the same time.

The interaction human being-machine, artificial intelligence, the multilanguage of the digital culture, open unexpected but ever more present scenarios with the creation of works where the analogical and digital dimensions unite themselves in order to emphasize experience.

From this point of view, design, integrated to an ergonomic approach and with an anthropocentric vision, becomes the key for understanding the modern complexity, which needs multidisciplinary knowledge to comprehend the necessities and then design proper solutions (Anselmi, 2009). It is a space for comparison between the sensitive and the intelligible, between illusion and shared beliefs, based on the relationship between the sensitive subject and the perceived object blending both into a horizon of sensations.

Therefore, design uses hints coming from other study fields connected to the theme of the body and it can contribute to enhancing the relationship between technologies and users, through a calibrated and conscious design.

As Norman highlights, the users interact with artefacts through the synergy of three different mental images. The first is the image inside the designer’s mind, “model of the designer”, then there is the one the user has of the asset and its functioning, “model of the user”, while the last one is the image of the entire system. In an ideal world the two models should be identical and therefore the user should understand and use the object in an appropriate manner. Unfortunately, not always designers communicate with the final users (Capece, 2017).

Besides undertaking the role of interpreter in order to offer proper answers, design becomes a strategic element for the interaction project, and it is capable to receive and satisfy not only the needs but also the desires of the target users. The designer must be able to completely integrate real and virtual dimensions to ensure that there is hybrid interaction between user, personal media and environment, while the information dynamics defines the interaction space at the intersection with daily experience.

Recently, virtual immersive reality has allowed users to experience the same sensations of property on an “other” body inside an immersive virtual environment that enables virtual reality users to experience the sensation of being “embodied” into a virtual body, the so-called “embodiment”, taking into consideration all the corresponding psychological and cognitive problems. It refers to being present and capable to interact in a space different from the real one, with the possibility to define oneself (Slater & Sanchez-Vives, 2016).
“We are at a moment when we can produce devices capable to induce sensations such as tactile perception of virtual objects, to simulate their presence and their movements and to increase the perception of the body itself as a mediator of movements and sensations. We can use infrared, optical sound, video, heat, movement and light sensors to provide sensitivity to the environment and we can determine the environment to react to the person’s needs by updating displays, activating engines, memorising data, guiding actuators, controllers, valves and by creating spaces where common objects acquire electronic features without losing the physical ones.” (freely translated from Arcagni, 2018).

Visual space gets amplified with the intention of directing different information and stimuli towards “the eye of the machine”. It seems that the entire building of the visual device is built around a deep hybridisation of different senses and sensoriality.

Research goes beyond sight and sound and we talk today about the “haptic skin” (Figure 3), able to translate virtual signals into physical sensations (Yu, Xie, Yu, et. al., 2019). Communication between user and machine is enabled due to the integration of technology in the skin, applying pressure, vibration or movement to the user due to an adherent electronic sheet that takes the shape of the body in a non-invasive, reversible way. Consequently, the sense of touch is induced to the person that wears the “skin” through vibrational actuators that reach a yellow or red color based on their levels of activation (Figure 4). There is a tendency towards the miniaturization of these elements in order to simulate the real sensations as much as possible (Tao, 2019).
The interfaces to be developed in the future will include more senses and will use technology to create multi-layered narrations. The interface becomes an area of experience and multidimensional encounter. Such dialogue can be considered active inside the interaction space, in a continuous retroactive feedback that affects the spectator’s behaviour.

While Turing claims that it would be enough to equip a machine with all senses in order to provide it with intelligence, according to Melvin Slater “an intelligent computer can be an immersive and sensory vision where the person gets introjected into a 360° visual universe. Thus, it acquires a complex view that includes a new sense of orientation and a new multisensoriality proper to the different experiential space” (freely translated from Arcagni, 2018).

With the intention to explore how can the variation of visual stimuli modify the perception of the surrounding environment and by analysing the mental and physical limits created by the human body in the physical reality, the Lumina project has been realized (Figure 5). Light has a fundamental role in interactive modelling made by the body that moves inside space, so that the users’ personal and peri-personal space are being explored.

Light reflection and refraction can create an intangible environment where the person can experience major self-awareness. 3D technologies and tracking systems have been used to determine the user’s position inside space. Through this project, the relationship between conscious and unconscious states of seeing/observing and the possibility to manipulate visual perception have been studied. Both the individual and the collective dimensions have been explored, with the support of both professional dancers and novices (Barra, 2019).
The narration of technology, as proposed by Uchida, curator of the Mirajkan Museum in Tokyo, represents a valuable stimulus to go beyond the overlapping between human being and machine and to identify an imagined coexistence oriented towards innovative aesthetics and original forms of interaction. The relationship between user and technology is supposed to evolve through a deep understanding of the artificial intelligence and its capacity to express feelings. The space becomes a fluid place/non-place to be explored, a real design element, an actor capable of stirring a physical and sensitive dialogue with the user, guiding him towards new emotional and perceptive experiences.

Different illuminated shapes are used to imitate the person’s movements (“Awakening”) and to increase the sensory awareness by providing the individual with the occasion to interact with technology in an unconventional way (“Autonomous”). The human presence activates the mechanical arm situated in the middle by transforming therefore the individual into main actor of the scene and by simulating a “dialogue” between technology and the human being. Various spheres of different dimensions that move in harmony by answering the visitor’s movements are subject of the “Accordance” area (Figure 6), while “Affiliation” and “Association” highlight the possible future intellectual and emotional interaction between human being and technologies, providing the occasion to express personal thoughts regarding the future of this relationship (Aouf, 2019b).
4. Designing a multi-layered interaction

We will live more and more restricted physical and virtual spaces, accelerating time and everyday life in search of fluid destinies through the “non-places of surmodernity” (Augé, 1995) to explore and rethink-redesign through the project and the design disciplines.

We will need to think about a new humanism keeping together works, innovation, techno-scientific thought, the capacities of the new intelligent machines and choosing which interactive model of social inclusion we tend to put into practice (Capece, 2017).

The models of interaction and the case-studies illustrated bring about an image of the different dynamics of the design world in order to respond to the new ways to enjoy cultural heritage. The complexity and articulation of the cultural offer imposes new design trends.

To this purpose, the digital language represents an interesting tool to favour the customizing fruition process by interpreting the human needs and transforming spaces into narrative places and work matter to define new immersive and experiential ways to know the territory and the cultural assets. The relationship human being-cultural asset is today mediated by technologies that can transform an inert connection into an interactive multi-layered journey, with outcomes that vary from learning to entertaining, being amazed or relaxing.
is necessary to take into consideration the contribution of neurosciences by orienting towards a multi-disciplinarity of thought in order to better understand the complexity of this relationship. This will allow reaching the “human technology oriented” model as a reference guide for the future, by putting, once again, technology at the service of the person (Matsushima, 2017).

Design can systematise the directing, technological and technical components and it can shape multimedia artefacts able to change the dynamics of communication of the cultural heritage at its different scales, from territory to artistic artefact.

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The role of Design in telepresence robotics experience.

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Abstract | The emerging role of telepresence robotics has led to increased interest on the subject, opening reflections on man-machine-man relationship and their acceptance in the contexts of application. The nature of telepresence robotics lies in the condition offered to users "to be there", in a place, although not physically, through a body, which allows the user to move freely in the spaces. The flexibility of this technology has extended its introduction and testing in high-impact social contexts, such as school, where the remote user for serious reasons may contact the individual or the community in a natural way. For this reason, it is necessary to investigate the perceptual and communicative aspects connected to this interaction and the technological ones, in order to outline an innovative design scenario both for the telepresence service and for the physical and digital artefact, where the robot will perform a very expected social task.

KEYWORDS | TELEPRESENCE, ROBOETHICS, INTERACTION DESIGN, UX DESIGN, SOCIAL INNOVATION
1. Introduction

Telepresence is a technology that integrates video conferencing and robotics systems, allowing one to be present in an environment, even if one is not physically there (Marvin, 1980). This offers the possibility to connect two remote locations, adding the value of movement and presence in that place to traditional systems. Many studies have revealed that a person’s quality of life is affected by their inability to participate in activities of daily living with family, friends, colleagues, which is often the case for people with special needs. Telepresence is a technology with great social potential, allowing one to be "virtually" present for people at a distance (Newhart, Warschauer & Sender, 2016). The promise of these robots is that they will be tools that can mediate communication in real time, in different contexts and enable accessibility on different scales. Although these systems have been around for several years and are mature in some areas such as the world of teleconferencing for businesses, there is still evolving research in some areas, especially in understanding their functional/behavioural potential and level of acceptance (Tsui, Desai, Yanco, & Uhlik, 2011). The use of telepresence robotics has attracted particular interest due to its ability to make places accessible that were not, either because of geographical and/or architectural barriers, or because of the special needs of certain individuals (Tsui et al., 2011). Examples of this new open dimension, aimed at overcoming barriers, speak to us of experiments in the context of schools, health care and support for the elderly. This experimentation scenario has given rise to actions capable of overcoming problems such as isolation and social exclusion of weak individuals (Bamoallem, Wodehouse, & Mair, 2014).

An interesting application in this sense, which still needs in-depth study, is in the world of education, where students who cannot participate in school activities have telepresence systems at their disposal. This allows them to watch the class, access content, communicate and interact with teachers and classmates. The use of telepresence robots can improve the life of the telepresence student by watching, listening, moving and interacting in a realistic, independent and live way. Despite the continuous development of technology, capable of supporting these new types of communication, there are still challenges to be faced, starting with a study of the application context and the users with whom to interface (Rae, Venolia, Tang & Molnar, 2015). In general, these robots are designed for a wide range of users and contexts: businesses, hotels, museums, hospitals and schools; this does not allow a distinction according to the context they are intended for, to the detriment of the effectiveness and engagement of the interaction (Figure 1). The impossibility of robots to make non-verbal gestures in support of communication also places a limit on the effectiveness of the message and interaction, but above all on the social presence of the remote user. The contribution aims to analyse human-robot-human interaction and the factors involved, with the potential to be developed. In this it will address in methodological terms the aspects to be applied to a project of experimentation of telepresence robotics in a university context. The aim is to arrive at a robotics project in which there is full knowledge
and awareness of the needs of the user and the reference context, through ethnographic research.

Figure 1. The most used telepresence robot models on the market: Double Robot, Beam, Beam Pro, Ohmni, VGo, Padbot.

2. Robots as a communication technology

The role of robots in everyday life is becoming increasingly important and their numbers will increase significantly in the near future. Service robotics in this regard aims to develop new solutions that can collaborate positively with humans. Telepresence robotics is an application of service robotics, which provides a virtual presence from a remote location, using a videoconferencing system (Kristoffersson, Coradeschi & Loutfi, 2013). Telepresence robotics represents a reference of particular interest in the field of social robots, especially in the field of socially assistive robotics (SAR) through interaction driven by user need through multimodal interfaces. In telepresence, interaction is not only between man-machine, but represents the means of human-machine-human connection, linking two or more individuals. Their nature is halfway between social and physical presence, which is why it is called co-presence in the literature (Nowak, 2001).

With this orientation, telepresence robotics has developed different levels of interaction: the first, between humans and the space to be explored or controlled through the machine, where the robot is an ocular prosthesis, although there is no shortage of examples that equip the body with prehensile arms or other aids; at the second level are those models that integrate camera and screen, using the tablet as an example, bringing people into visual and
auditory connection; while the third level, of more recent configuration, in addition to connecting people through live digital images, aims at the possibility of being directly piloted by both people, in a form that we might now call co-piloting (Desai, et al., 2011). Some features are common to all levels of telepresence: the ability to move, to connect, to videoconference, and to be equipped with sensors. Each of these can be important in reinforcing the human presence in distance communication, enriched also by that set of elements that can characterise and increase the sense of closeness, just as happens between people in face-to-face communication. And it is also by working on the elements proper to social presence that this perception can be improved: by implementing the video and audio system and the ability of the robot to move in the coverage paths, and not only this dimension, because we already have robots capable of moving with a certain level of naturalness of human memory (Vu, Rissanen, Pang & Foo, 2012). In a telepresence system it is therefore essential to consider the ways in which we are able to reinforce a real perception of closeness with the remote user, including through non-verbal communication. In fact, research, such as that of Mehrabian (1980), claims the non-verbal language of communication to be more important than the mere reproduction of words.

3. Robotics project definition

The possibility of connecting people remotely and having them participate in everyday activities has allowed telepresence robotics to be used in experimental activities in different social contexts, allowing issues such as inclusion and accessibility to be addressed (Moyle, Jones, Dwan, Ownsworth & Sung, 2018). The robots used in these experimental and research contexts are the same as those intended for work environments, for which they were born, and for this reason satisfactory results are not returned in terms of a User Centered Design approach. What is needed is a design in which the user is at the centre of the project with his or her own needs and the context for which the robot is intended (Casiddu & Micheli, 2011). The continuous evolution of these artefacts, mainly from a functional point of view, has led to unresolved issues such as the acceptance and ethics of the robot.

Consequently, it is necessary for a robotics project to be explored and compared by different competences, which no longer include only mechatronic and computer engineering, but also disciplines from the humanistic sphere. This leads to a simplification of the highly sophisticated engineering approach to have artefacts that reflect social and cultural changes. The different disciplines (anthropology, psychology, design, engineering) can contribute to the development of answers in terms of robot adoption and perception, through a holistic approach to the topic, in which Design assumes the role of knowledge mediator (Germak, Lupetti & Giuliani, 2015).

Design is among the disciplines that can make a significant contribution at different levels of the robotic project: expressive (in terms of appearance and morphology), passing through language, behaviours and interactions with the user. The contribution can be consolidated
and extended by adopting a co-design approach, in which the actors of the system are involved, bringing knowledge for a shared and accepted robotics project (Freeman, 1984). Through design, robotics can expand its competences to generate value and meaning, creating continuous relationships between technology, human needs and context.

Consequently, telepresence robotics products need further reflection based on the actors and the context of interaction (Stappers & Sanders, 2003). Indeed, in the literature there are more and more experiments in which robots are personalised by the user, even simply through a garment, to identify who is representing the robot.

3.1 Acceptance factors

The concept of acceptance is central to human-robot interaction, as users must be enabled to interact with the tool in a natural and intuitive way. Acceptance of robots depends on several variables and is defined as the robot’s ability to fit into a person’s life and willingness to be used in the long term (Broadbent et al., 2009).

When designing these artefacts and their interaction with humans, reference is always made to the human body, which is the starting point. However, the continuous search for the resemblance of machines to humans faces several challenges, including Uncanny Valley (Mori, 2012). In general, people are more likely to interact with humanoid robots, but there is a limit beyond which a sense of proxemic insecurity is created in humans as the distances between the two decrease. Assessments are therefore required regarding the physical, expressive and empathic clarity through which the technology becomes recognisable and acceptable (Salvini, Laschi & Dario, 2010), because it is assumed that people's attitudes towards robots are influenced by their appearance and personality, which in turn influence their acceptance (Kiesler & Goetz, 2002). Conceiving, planning and designing robots therefore also requires an effort to anticipate the future, to simulate ideal scenarios, in which pervasive technologies find a balance with the social and cultural dimension of humans, made up above all of relationships with other individuals and with the context (Šabanović, 2010). For this reason, the role and effect of human resemblance must be investigated in different cases and in the final rendering, especially when the morphology of the robot differs from the human one, albeit with a new language, as in the case of telepresence robotics. Precisely in this area, it is necessary to investigate body language and non-verbal gestures, which play an essential role in communication between individuals, enhancing the remote user’s sense of presence. Telepresence robots need a deeper investigation into the possibility of extending the language and communication they express.
3.2 Robots as a somatic configuration

Gestures represent an extremely important communication mechanism that allows people to accompany speech and contribute to interaction (Stahl, Anastasiou & Latour, 2018). What is missing in telepresence robots today is the ability to express hand gestures and body posture. Several studies show that the acquisition and mastery of gestures is an essential aspect of human cognitive development, and that gestures not only express their thought, but can also be considered a factor influencing the development of thought itself. Gestures facilitate group communication, as pointing or moving shared objects during a discussion provides a clear spatial relationship for the communicator and group members (Björnfot & Kaptelinin, 2017).

The telepresence robots we find on the market today have very specific morphological characteristics: the head represented by a camera/display (usually a tablet), the body by a vertical rod and the feet by a base with wheels. With a few minimal design gestures, these robots allude to the morphology of the human skeleton, becoming humanised machines with a new language. However, their new morphology still needs some improvements, including non-verbal communication, which is currently absent. Some have tried to equip these robots with arms to overcome these limitations, such as ProP, an experimental telepresence robot equipped with a pointing device resembling a human arm. Another example is the QB robot (Slack et al., 2018), equipped with an anthropomorphic hand manipulator to allow interaction closer to the local user, and have a positive social experience. Moreover, on movement it worked a lot, as it represents a characterizing element of the interaction with the robot, both in terms of naturalness and fluidity, as it represents the biological nature of human characters (Kupferberg, Glasauer, Huber, Knoll & Brandt, 2001). However, if these performances fail and the variety of gestures is limited and repetitive, to highlight the mechanical origin of the robot, the user tends to become detached and uninvolved in the interaction. Human-robot communication codes will therefore assume great importance, implementing those that telepresence already guarantees through the display.

4. Telepresence: an ethical issue

With the advent of service robotics, ethical considerations regarding the privacy and security of users have been raised. An increasing number of robots are entering spaces lived in by humans: private or public spaces, often equipped with cameras and sensors, such as telepresence robots, capable of collecting data (Niemelä, van Aerschot, Tammela, Aaltonen & Lammi, 2019). Telepresence robotics still raises some concerns especially due to the presence of the camera that can collect sensitive data. This is precisely why privacy and security are considered the main barriers for the continued growth in the adoption of these technologies. The ability of telepresence systems to move within remote spaces, even if guided by cameras, raises questions about the physical safety of the user, the environment,
The role of Design in telepresence robotics experience

and the robot itself. The robot must be designed to be safe in the environment in which it moves, with the right technological devices. For example, whenever the robot moves, it should provide some form of feedback to people, thus improving interaction with users and ensuring a way to prevent harm. At the same time, the robot should be able to avoid collisions, either against static obstacles or other people. Giving the remote user a physical body equipped with a camera raises additional privacy issues related to the subjects participating in the conversation and the environments being filmed (Krupp, Rueben, Grimm & Smart, 2017).

Regarding the issue of privacy, Calo (2010) in his book Robot Ethics writes the chapter Robot and Privacy where he summarises the rapid trend of robots towards ubiquity and identifies three main dangers posed by robots in relation to privacy: surveillance, access to private living and working spaces and social impact. These issues translate into the continuous search to solutions for the disclosure of sensitive data related to the user who is not always aware of what is going on. Compromise systems between privacy and the usefulness of robots in the context of their application, for the performance of activities for the creation of human well-being, must therefore be developed. Having a mobile robot equipped with a camera within an environment raises several concerns. Among these is that the robot can be guided, after authorised access by the remote user, to visit and retrieve location data. This also means that unauthorised access is possible and that software security can be circumvented. The data collected by the robot for its operations in the environment must remain inaccessible from the outside, remaining encrypted and authenticated. Unfortunately, these conditions of uncertainty and instability of the technology make its adoption limited despite its great potential in different application contexts. An ethical project must consider these issues from the earliest stages, to arrive at a final product that is accepted by the user who establishes a relationship of trust in its use.

5. Robotics in Education

The education sector, like many others, has faced several changes with the rapid growth of digital technologies and robotics. Education systems have been able to exploit the new opportunities of robotics, which have made the sector more collaborative and accessible to students with different needs. Indeed, robots are considered useful tools to include those with learning difficulties and disabilities in classroom activities, especially with the use of social robotics (Robins, Dautenhahn & Dickerson, 2009). Robots in these environments are used in different ways: from robots as tutors or classmates, to telepresence robots as assistants and teachers (Sharkey, 2016). In the education environment, experiences managed through telepresence support school learning for students who cannot reach school, but also experiences of cultural and language exchange between different groups, where for example new languages are learned with telepresent native teachers. Noteworthy is the fact that the robot can promote collaboration between different actors interacting with each other, with a view to achieve a common goal; this especially in the educational
field allows learning not only by interacting with the artefacts themselves, but by sharing common goals among students, improving their social and relational skills among them. The robot responds to the needs of modern society and manages to be an important tool to increase the motivation of users who interact with it, to be protagonists of the learning process (Benitti, 2012). But even in this context it is clear how the perception of the robot changes according to the different age groups of students and therefore how different measures are needed for a successful interaction. For example, a school-age child does not perceive the robot as a mechatronic device but gives it a set of characteristics that are generally associated with living beings, animism (Piaget, 1929), contrary to what an adult perceives. Most telepresence robots have an industrial appearance, and this affects the developmental needs of different users such as children, who have particular needs relating to the expression of their identity. just think of the personalisation of technology that takes place all the time, through mobile phone covers, tablets.

5.1 Telepresence in education system: case study in university spaces

The school is a social environment of development and growth, where different groups (teachers, students, administrators, and parents) interact to shape the student’s life experiences. In the school context we are confronted with different needs, ranging from the development of the student’s identity, image, integration, and affirmation within the group. Attending school has positive effects on the student’s self-esteem and contributes to making him an individual capable of relating to society.

In many situations, students find themselves having to leave school for short or long periods of time for health reasons. The provision of training services must be the preventive factor with negative psychosocial consequences. Data emerging from the literature show that students who are unable to attend school face learning difficulties and subsequent problems with social integration (Reis, Martins, Martins, Sousa & Barroso, 2018). Few experiments attempt to address this problem by adopting telepresence robots, with which absent students can go to school, albeit at a distance, finding themselves in a wide variety of situations that change daily. This has made it possible to ensure the physical accessibility of classes and content offered by teachers to distant students. This type of intervention occurs mainly in the early grades of education (primary and secondary), to the detriment of the university context which is still little investigated (Reis et al. 2017). Some solutions for the university are those related to e-learning courses, which offer the possibility of autonomously managing the times and modes of their study, but at the expense of the interaction between student and teacher that fails. Telepresence could therefore eliminate this distance and create new opportunities. The few research on telepresence robots in the university context are those for cultural exchanges with other universities and distance learning for professionals. This is the case at Duke University, where telepresence robots have been used as a teaching tool to engage nursing students in clinical simulations to be passed on to early college students (Shaw et al. 2018).
The role of Design in telepresence robotics experience

From this analysis of telepresence robotics in education, new challenges, and research on the context of the university that we intend to investigate and analyse arise. An analysis that involves observing the interaction of students within environments with telepresence robots. The latter will have to be tested by users and evaluated, based on the market offer of existing models, through a multi-criteria methodology to understand the limitations and opportunities for the development of new applications (Elara, Rojas & Chua, 2014). Observation with shadowing techniques will allow to collect data on the interaction between the user and robot, to obtain an understanding of the factors that influence it. As already introduced, a co-design approach is necessary for the success of a user-accepted product, where users are involved in each phase of experimentation and design, where needs are interpreted by different figures. Participatory design succeeds in bringing out the continuous changes between society and technology. With a co-design approach, it is possible to consider the context for which a project is designed with user observation as a tool to investigate the scenario and develop a new proposal. For example, the possibility of co-piloting from both places of these robots, or the possibility of being able to transmit the communication message through body signals. A telepresence robot should be able to express the emotions and moods of the user it is impersonating, thus creating interaction scenarios that are more natural and closer to other users. Emotional design helps to support the design of such artefacts and the creation of innovative interaction scenarios, in which communication must be in a language alluding to that of human beings.

Designing robots for specific environments, such as the educational context, therefore means considering different variables involved in the process to avoid failures, ranging from the perception of the usefulness of the tool, to the level of complexity in terms of usability,
to the study of the robot's own forms of communication (expressivity, movement, speech), because it is known that its acceptance also depends on its appearance and personality (Kiesler & Goetz, 2002).

6. Conclusion and future works

The reflections reported on the technological development of telepresence robotics and the creation of new strategies, capable of managing the relationship between man and machine, are necessary to increase the level of acceptance of these robots, in order to improve their coexistence with man. In this direction, design plays a key role in shifting the focus from a technology-driven process to one in which an ethical approach and acceptance are characteristic. This means putting people, the community, their needs and the social context at the centre of design, to achieve the main requirements of interaction: empathy, involvement and collaboration (Fitter et al., 2018). Evaluating. As with all interactive systems, the experience of the user interacting with the robot needs to achieve benefits, so it needs to be intelligently designed. UX with social robots, such as telepresence robots, must be a central issue in the development of such artefacts (Germak, Lupetti & Giuliano, 2015). The paper introduces several issues related to telepresence, such as the context of use of telepresence, the target user groups and the lack of non-verbal communication to support the interaction. Security and privacy aspects that are still present in these robots and that need an adequate and conscious design must also be considered. Through a co-design approach with the different actors and entities, which take part in the project, it is possible to create a collaborative system, where the maximum transparency and the purpose of the intervention itself is present. Therefore, this study intends to promote and continue the experimentation of a service Robotics in situations of discomfort or impossibility of physical encounter of the university student at a distance, where the robot is a tool for inclusion and social progress, through the creation of a new physical service.

References


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The Venice Backup: Case studies on the use of Virtual Preservation Techniques on Architectural Heritage sites in Venice, Italy.

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Abstract | The paper documents three case studies researching techniques of ‘Virtual Preservation’ upon heritage sites in Venice, Italy. The case studies had the goal of determining whether mixed-reality techniques offer a viable solution to the potential loss of heritage sites which in the near future could be irreparably damaged by the impact of climate change. While many studies of 3D-scanning of heritage sites exist, the study attempted to be the first comprehensive study to both look at their reproduction in mixed-reality and further to look at the possibility of digitally recreating the “atmosphere” of an entire city, in this case that of Venice, which is one of the most historically valuable cities in the world, and also one of the most precariously exposed to climate change. The use of this mixed-reality technology included ‘reality capturing’ through 3D-scanning data, which then were transferred to ‘virtual reality’ through various point-cloud data processing tools and through the use of the gaming engine Unity with a custom software plugin to display the point-cloud data. In order to test this hypothesis, the studies tested various conditions and atmospheres of the city and therefore the case studies were performed over several months, and vary in scale, light conditions, and type; from the Nordic Pavilion in the Giardini, to the streets of Cannaregio at night, to the Island of San Servolo during the day. These digital replicas were then tested upon various audiences, ranging from heritage experts, students, and the lay public. The article concludes on illustrating the limitations and strengths of these methods while foreseeing how such case studies could help experts to establish guidelines on integrating mixed-reality into traditional practice of architectural heritage and preservation, government guidelines, and partnerships with the technology sector, with the ultimate goal of suggesting such case studies provide evidence for the viability of producing realistic alternatives to mass cultural heritage loss due to climate change in the near future.

KEYWORDS | VIRTUAL PRESERVATION, MIXED-REALITY, ARCHITECTURAL HERITAGE, VENICE, CLIMATE CHANGE
1. Introduction

1.1 Mixed-reality in Architecture

Recent technological developments within ‘mixed-reality’ technology have the potential to significantly impact the architectural profession. These recent technological developments have been analyzed and theorized in part by the architectural community through their capacity to provide new knowledge and tools regarding the layering of digital and physical space (Bratton, 2014), their applicability to “intelligent” spatial practice (Picon, 2015) and through a general strategy of working on the “smart city” (de Lange, et alii, 2019). Others have noticed how this technology will impact architectural preservation and heritage studies, especially within the field of ‘experimental preservation’ (Otero-Pailos, Fenstad Langdalen and Arrhenius, 2016), and more specifically how these working methods may apply to architectural heritage practice more generally (Buthke et alii, 2020). Scholars additionally have noticed how using mixed-reality in urban planning will be “affect community and place-making efforts” (Berck, 2017), with even organizations like the UN Habitat recommending such tools for public participation in urban and public space design (UN Habitat, 2019). Together this signals a broad range of recent scholarship claiming the relevance of mixed-reality to architecture.

Figure 1. Example of Mixed-reality application to healthcare scenario. Top right, top left and bottom left: Users in laboratory setting. Bottom right: Inside of the digital architectural replica. Source: Haptiq – Facebook post, 2020.
Expanding upon this rich and rapidly developing research territory, the primary framework of the research for this paper regards the potential for this ‘mixed-reality’ technology to be applied to various aspects of the architectural profession in hope of both understanding the technologies in their current development while identifying relevant uses within a framework of architectural activities in urban planning, city design and other relevant professional tasks such as heritage studies. Here, ‘mixed-reality’ is used as a blanket term to describe several new terms and techniques including augmented reality, virtual reality, 3d-scanning and photogrammetry (also known as reality capturing), which for the purpose of the study can be framed as an overall development of technology becoming increasingly “spatial” (Barford, 2015). The term ‘architectural profession’ is meant to describe the various professional tasks performed by architects, including architectural design, city planning, construction management, architectural research, teaching, and architectural heritage and preservation. The goal of this study is then to provide case study data on the potential benefits and/or downfalls of these ‘mixed-reality’ technologies upon a defined scope of professional architectural responsibilities.

Figure 2. Mixed-reality when applied to Architectural research in an academic setting. Left: Instructors within student-design Mixed-reality project. Right: View from inside the space. Source: Author, 2017.

1.2 Use Cases for Mixed-Reality

One of the primary interests of the research is thus to understand how various claims regarding the possibilities of these mixed-reality technologies coincide with their potential use cases. If the possibilities of mixed-reality indeed are true, the technologies could allow physical space to be digitized with a very high degree of accuracy, and to be recreated in a manner which allows people to experience such a digital replica as a full-body spatial experience. This is to be made possible on the one hand due to a range of techniques within ‘reality capturing’, which uses 3d laser scanners, photogrammetry, and other methods which claim to create 3d-models with highly accurate positional data in addition to highly accurate
color data. With high-end hardware and state-of-the-art software, such reality capturing portrays the creation of 3D models with near perfect, millimeter accuracy, and highly realistic color representation. Using sound recording techniques known as field recording, one may also capture highly accurate sound data. On the other hand, virtual reality and augmented reality technologies, including headsets, sensors, and mobile devices, claim to produce highly accurate 1:1 bodily experiences of such digital space. This is demonstrated to be made possible due to the virtual and augmented reality hardware being able to position itself accurately in relation to a digital model within a physical environment.

Figure 3. Mixed-reality when applied to Architectural research in an academic setting. Source: Author, 2017.

1.3 Architectural Heritage as Use Case

One of the more promising developments within this research framework is the potential usefulness in using such mixed-reality techniques when working with architectural heritage sites. Specifically, 3D scanning, virtual and augmented reality provide new opportunities to catalogue and archive buildings and physical spaces even in/at full scale (Buthke et alii, 2020). The possibility for technology to create digital copies of physical heritage sites which also can be experienced at full scale within a virtual exhibition or archive has numerous benefits to existing working methods within architectural heritage, while simultaneously opening potential new use cases entirely. This is due to architects requiring a high degree of accuracy required when working with heritage sites, often experiencing challenges due to the often
precarious state of material aspects of heritage sites, the difficulties related to the costs and
difficulty of travel to and from heritage sites, and difficulties in coordinating accurate and
precise data about a site. This is further exacerbated by tourists and the public’s interest in
visiting heritage sites, limited economic resources in maintaining heritage sites, and experts
and maintenance needs for an enclosed and undisturbed working area when performing
maintenance, conducting studies or building modifications or support structures for a site.

![Image](image_url)

*Figure 4. Mixed-reality when applied to Architectural Heritage in an academic setting. Student views a 3d-scanned Heritage site through the HTC Vive Headset. Source: Author, 2019.*

### 1.4 Architectural Heritage and Climate Change

All of these aforementioned issues meet a particularly challenging extreme when confronted
by erosion, material decay, and extreme weather events which can be particularly
destructive to historical sites. There is now broad consensus among international scientists
and NGOs that climate change poses a severe threat to the Cultural Heritage sites (Gruber,
2011). Numerous international reports document how climate change will further escalate
these effects, with potentially disastrous consequences for heritage sites along coastal and
equatorial areas in the near future. This is due to both the predicted escalation in frequency
and strength of weather events in general, and the effects of sea rise and its effects upon
communities which maintain heritage sites due to climate migration forcing the likely
abandonment of heritage sites. These extreme effects have the potential to abandon large
amounts of heritage sites globally both by their local communities and by tourists and other
groups which previously would provide cultural and economic incentive for maintenance of
the sites. In this we see that climate change poses a unique threat to heritage sites which
seek new methods and strategies for adaptation and survival.
While several actions have been contemplated in the short term to prevent the impacts of Climate Change on World Heritage properties, according to interviews with experts on the topic, there is limited experimental research accomplished to date on the process of adaptation of cultural heritage to climate change (Sesana et alii, 2018). Already in the 2007 World Heritage Committee report it was claimed that there is a need for more research on the effects of Climate Change on both the physical heritage and the social and cultural processes that they are a part of (Colette, 2007). The report subsequently suggested that case studies could be used as experimental pilot sites for the development of appropriate strategies. From these examples a number of key principles can be derived on which sustainable adaptive responses to Climate Change can be developed, including «[…] designing flexible management planning objectives to enable priorities to be re-evaluated in response to Climate Change» (Colette, 2007). It is particularly noteworthy that there is still little research to date on how virtual preservation techniques may be utilized to archive potential heritage loss before its destruction.
1.5 Mixed-Reality applied to Climate Change

As recent reports document how heritage requires more experimental solutions to climate change, we find here a growing acknowledgement within heritage experts and preservationists to find new, experimental methods to stop and prevent cultural heritage destruction, specifically through research applied to case studies (Negussie, 2012). Within architectural education and research, the field of ‘experimental preservation’ has recently opened to the opportunity to evaluate new methods, technologies, and pedagogical strategies in relation to both climate change. Thus, although such ‘Virtual Preservation’ techniques demand a substantial change of established working methods and tools within architectural heritage, the realism obtained through such methods could compensate for the loss of the original material site, and still allow future generations to experience heritage sites in the future through digital means.
2. Methodology

2.1 Goals for the experimentation

The article’s introduction to the topic of ‘Virtual Preservation’ and its relevance to mixed-reality technology development, architectural use cases, the field of architectural heritage, and the problems regarding loss of heritage sites due to climate change, provide the overall goal of evaluating whether virtual preservation replicas of heritage sites have sufficient accuracy and user experience to compensate for the high possibility that climate change and other environmental factors will destroy a vast amount of cultural heritage sites globally during the coming future. For this goal to be tested, heritage sites of relevant interest needed to be identified, and ways in which to technically achieve the studies had to be researched, and equipment acquired and planned out. Finally, relevant venues and methods for testing these cases upon users needed to be identified and planned.

2.2 Equipment

Between 2016-2019 the research tested various equipment. For this specific study, the best possible equipment within realistic means was utilized. This included the Leica BLK 360 3d scanner, the software package of Autodesk Recap, the iPad Pro (2019 model), and the newest software versions of Unity, including a custom plugin for converting large point-clouds to virtual reality. For the implementation of virtual reality, the case studies utilized the HTC Vive and HTC Vive 2 headsets, with corresponding sensors and trackers.

2.3 Case studies

The case study site of the city of Venice, Italy was chosen due to Venice’ heritage status as well as its precarious situation due to climate change in its lagoon setting. Venice in general is also one of Europe’s most endangered cities with flooding and sea rise due to climate change becoming a rampant problem. This, in combination with the endangered state of the heritage sites itself, presented a highly relevant context in which to experiment with the virtual preservation topic.

The study researched thus the application of virtual preservation to architectural heritage sites in Venice. As initial research revealed that such research had yet to be done in a structured manner, the study was executed as a research-by-design study involving the design, execution, and evaluation of prototypical case studies within scenarios in Venice. The case studies focused on the following main points: i) the capacity to identify applicable sites to perform virtual preservation methods upon; ii) the capacity to transfer physical data from heritage sites into virtual reality through 3d scanning, surveying and modelling; iii) the
capacity to experience the heritage sites at full body scale in to virtual reality and then to evaluate to what degree they provide a fair representation of the archived space.

**Figure 8. Flooding in Venice during the research period, February 2019. Credit: Author**

### 2.4 Choice of Case Studies

The study was conducted through 3 case studies: 1) Nordic Pavilion in the Giardini, during daytime; 2) San Servolo Island at daytime; and; 3) The streets of Cannaregio at night time. These case studies were chosen due to their ability to represent a “totally” of typical venetian scenarios: Singular buildings, streets and alleys, and buildings with connections to water. The case studies were relevant to the research topic of climate change in various manners. All case studies were challenged by a context that presented some form of erosion of other environmental stress. Finally, all case studies were of a scale that was possible to perform a study within a few days period and to be replicated within a feasible framework in terms of file size, equipment, and manpower.

### 3. Case Studies

#### 3.1 Format for each case study

In each case study, the scanned models were recreated at full-scale using mixed reality methods to create an exhibition of the site. For this, the point cloud models and had to be processed and documented, and then imported into the software engine of Unity. Within Unity, the models were then reconstructed as virtual reality experiences through the SteamVR plugin. This was then exported to the HTC Vive VR headset with the attached equipment. Each case study was presented in a setting with expert participants experiencing the virtual exhibitions of the archived spaces. The results allowed to the studies to produce a
high definition representation of the heritage site in a virtual environment. The virtual environments were used as a means to increase dialogue with the public and heritage authorities as well as to experiment with historic restoration. The participants within each case study provided feedback on the extent to which the experience resembled a physical experience. In several case studies, participants experienced both the physical and virtual spaces, allowing for comparison. The feedback was documented and processed for further research and to draw initial conclusions as to whether the experiments could provide guidelines for further implementation of virtual presentation in addressing the aforementioned challenges to climate change.

3.2 Case Study 1: The Nordic Pavilion, Giardini, Venice

The first case study was a highly ambitious endeavour. The manpower provided for the site included a group of 8 students within a research course dedicated to the preservation studies of the Nordic Pavilion in Giardini in Venice, in addition to 3 dedicated staff members on the heritage site charged with caretaking and maintenance of the site. This provided critical assistance in cleaning the site and removing rubbish, access to various rooms and spaces, etc.

Figure 9. On-site scanning of the Nordic Pavilion. Note the vacancy required for the scan to be performed. Credit: Author

The case study was technically and physically ambitious in multiple ways. The case study was the first attempt at creating an entire, full resolution virtual exhibition of a large building at this scale, with high enough density of the point cloud to recreate material quality in a state-of-the-art manner, ie to be reproduced digitally as an exact replica. It was also the first to integrate live, multi-input sound. Due to the size of the site, the 3d scanning had to be
The Venice Backup

executed over two days and consisted of 25 scanning points. At around 10 minutes per scan, this involved a significant time span. The point cloud which was then generated consisted of a large amount of data which required an extensive amount of time dedicated to post-processing and recreated in Unity and compiled into virtual reality. The study was then recreated in an exhibition format in Oslo, Norway for heritage experts and preservationists. The virtual experience was presented to a range of experts discussing various topics regarding the history and restoration of the building.

Figure 10. Initial testing of the Point-cloud data in the Autodesk Recap interface. Here, the point cloud is reduced to 100mmx100mm density. Credit: Author
Among primary drawbacks from the study was learning that point cloud scan of such magnitude produces a very large amount of data, emphasizing the importance of either reducing point cloud data in early stages, or acquiring sufficiently powerful hardware in which to operate with the point-cloud afterward. In this instance, only 8 of the original 25 scans could be utilized with the available hardware, though all 25 scans can indeed be used provided a powerful enough computer.

The study also produced the acute observation of difficulty of entering active heritage sites as maintenance personnel and other crew members had to either be removed from the site to perform the study, or removed digitally afterwards. This meant that several “ghosts” had to be deleted from the point-cloud after the fact. Finally, weather conditions for the study proved to be (luckily) favourable, though had the weather been more difficult the study would likely not have been feasible within the provided time frame. This is due to the color and reflection of the materials, when scanned, provide a more of less exact representation of the shadow and light conditions when scanned, and when scanned over two full days, require relatively similar conditions of this time period for the point-cloud to appear cohesive. Luckily, the weather was overcast sky for nearly two consecutive days, providing nearly optimal conditions.
The primary developments of the study was that a realistic, nearly perfect copy of the site was indeed achieved – generating rich dialogue between heritage experts, students and the public about the history and the future of the pavilion. In particular, the data was used for several studies related to a temporary exhibition in the space for the 2020 Venice biennale. This realization - combined with the knowledge that the technology could provide an accurate and high-resolution experience, further elevated the capacity that virtual preservation could provide unique opportunities to the field.

3.3. Case study 2: San Servolo Island

The second case study expanded on the first case study in numerous ways. It was performed on the Island of San Servolo, during the daytime, for a period of roughly 6 hours. The study consisted of roughly 25 scans points. As the site consisted of an island typology with a ferry landing, a large building interior and several courtyards between the building mass, the site was therefore interesting because it included a waterfront in close connection to the edge of the building, a large building complex, and several outdoor areas. It was also chosen because it was largely uninhabited during the daytime, allowing the study to be performed without much disruption from the public or other authorities within the site.
The weather conditions and other practical considerations for the study were favourable – providing generally good scan data. The equipment had to be moved in rapid succession between indoor and outdoor areas. This proved to be successful – offering an interesting data set of an entire spatial transition between different spaces of varying scale, material quality, color, connection to water and the exterior, etc.

One difficulty which arose was a transition between a central lobby area into the courtyard. Here, a lobby area with a heavy door which could not be left open broke the scan into two separate components. This meant that the scan consisted of two final outputs: the ferry exterior area and the interior and courtyard areas on the other side of the lobby. This highlighted some of the difficulties in created entire scans of a complex building configuration suggesting that such studies require a large degree of control and planning when moving across large areas in hope of documenting an entire continuous area.

Upon experience in the virtual reality model of the site, students and heritage experts in the lab reported on the accuracy of the study being of sufficient accuracy to recreate a authentic and valuable heritage study. Particularly, the ability to pass through multiple rooms from indoor to outdoor provided interesting feedback. Here, the size of the study meant that users had to “teleport” between vantage points rather than simply meander around like in the previous study. This suggests that possibilities for movement in large virtual spaces will require further study and likely new technical solutions.
Figure 15. Point-cloud model of San Servolo Site. Notice how multiple spaces are recorded by moving the scanner to multiple points. Credit: Author

Figure 16. Student studying the San Servolo project in the lab. Note how the size of the lab reduces the ability to walk within the entire model, requiring users to “teleport” to different areas of the space. Credit: Author
3.3 Case Study 3: Cannaregio streets at night time.

The first two studies documented scenes in Venice during the daytime. This prompted this interest in attempting to perform a study of Venice during the night time. One of the reasons for this interest is that many of the unique qualities of Venice streets are indeed most prevalent during the evening, especially when the unique qualities of darkness and street lights are noticed. This also provided a good opportunity to test the technologies’ ability to capture such a scene accurately during the night. Finally, the night environment allowed to have more quiet and less disturbance than would normally occur during the day.

![Figure 17. Performing the case study in Cannaregio at night time. Note the quality of the typical Venice street scene during the night.](image)

Cannaregio was chosen as a site as it is often characterized as one of the more beautiful areas of Venice with a coherent network of buildings, piazzas and canals offering a typical and cohesive study of typical Venetian street environments. The study had the goal of documenting a typical stretch of streets during the night, and was therefore performed during a period of approximately 5 hours and consisted of 22 scan points over a territory of roughly 200 meters, from roughly 21:00 at night to 02:00 in the morning. The study started near Calle Zancani, crossed the Campo san Marziale, and ended near Calle Trevisan. The scan points were between 5 and 15 meters apart depending on the context. The scan was performed by two persons. The night time context provided much less difficulty that daytime scans as there was much less public activity in the streets.
The study was collected in the Autodesk Recap software and compiled into a 3d model. Initial inspections of the data showed that the study had been successful in scanning a long stretch of streets with a comprehensive network of canals, buildings, and piazzas with a high degree of accuracy in the scan. Particularly, light and color data was remarkably accurately portrayed. This seemed to verify the hypothesis that it would be possible to perform such a study during the night.

The data with further compiled and brought into virtual reality for further study. Experts, students, and visitors from the lay public were invited into the lab to experience the scan. Initial feedback from the audiences consisted of the scan being both highly experiential and beautiful. Particularly, the street lights combined with the high level of darkness was reported as especially intriguing and beautiful. It was also pointed out that the long stretch of space the scan contained allowed for a short “walk” through Venice. Multiple users reported this aspect to be an interesting experience. Feedback regarding teleportation was similar to the second case study. This suggests that some of the unique qualities of Venetian street life during the night time could indeed be captured and recreated in virtual reality with such methods, but will require new techniques for virtual movement.
4. Conclusions

4.1 Workflow

This study was able to demonstrate that significant improvements in the technology have happened in the past years which likely would not have made such a study feasible previous. In 2016, there were several limitations the virtual preservation. One of the primary limitations of previous studies is that in many cases the information collected was not be accurate enough to be recreated as a full historically correct documentation of a heritage site. The technical capacity was often a limit in the collection of data. Upon inspection of the data collection with this selection of hardware and software, it seems that this accuracy is no longer an issue.

4.2 Significant difficulties

The study was limited to a total of three sites which had the purpose of documenting what types of difficulties and benefits such methods could have. In particular, monetary costs and technology competence are likely to be significant challenges in performing this type of
The Venice Backup

work. The Leica BLK360 scanner was an expensive piece of hardware that is not available for mass use, and requires specific supervision and care. Additionally, comprehensive and precise virtual preservation studies of this manner cultural involve much travelling, which places stress on budgets and time constraints. In addition, completing accurate renderings of a site demand storage capacity of large-sized files, and specific competence on how to transfer data, handle point clouds, convert geometry, etc, which due to their highly technical nature places such studies within a specialist discipline. These findings in large portray the field as likely too dependent on specific competence, and too expensive, to be utilized en mass.

4.3 Significant findings, overall

The study had several significant findings. The most significant breakthrough of the study is that it illustrated that available technologies today allow for full-scale digital copies of heritage sites to be transported into virtual reality and recreated in a full-scale exhibition to be experienced by an audience. It also, importantly, and perhaps for the first time, demonstrated that such studies could be performed on a variety of sites and with different lighting conditions with the ability to capture both daytime and nighttime atmospheres in order to capture a variety of environments encapsulating an entire “feeling” of a city. This offers the potential to create experiences of an entire city such as Venice, demonstrating the capacity for such techniques the create strategies not only for a specific heritage site, but possibly for an entire city. This offered an interesting way to understand how such techniques can be used beyond mere technical documentation and towards the ability to recreate specific, historically valuable experiences.

4.4 Significant findings related to User feedback

Displaying virtual reality representations of heritage sites to audiences is a highly intimate experience, creating unique opportunities and challenges. As the technology in its beginning stages, some users get very dizzy, which creates a significant challenge for inclusivity. The virtual reality representations require a high degree of trust between users, as they may end up looking foolish in front of each other. The highly technical aspect of the technology requires additional supervision and dedicated staff with sufficient expertise. The spatial and economic properties of the technology require exhibition review formats and demand new approaches to studio space. Virtual reality requires a dedicated lab with a designated space for optimal comfort. This has the potential to create a class divide among users, which should be avoided. The use of proprietary software requires practitioners to familiarize themselves with different software packages and to make informed choices about the correct software to use. These combined challenges signalize the need for increased research into multidisciplinary applications of technology.
Through polling the audiences and in dialogue with experts during the exhibitions of the sites, it was established that the virtual preservation studies recreated heritage sites in sufficient resolution for the experiences of the sites to be recreated in a manner that was representative of the physical space. Overall the feedback from the study, despite several difficulties, allude towards a position that verifies the initial research hypothesis that these methods could propose viable answers to the problems of potential mass loss to built heritage due to climate change. In addition, the use of virtual reality technology within preservation gave the opportunity to speculate upon a new form of emerging preservation practice which can work directly with the preservation of heritage sites as a full-scale medium, fostering new relationships between preservationists, architects, and the public.

Figure 20. Interior of Case study 1, currently being used for a proposal within the building for the 2020 Venice Biennale. This shows the applicable uses for such techniques in current architectural practice. Credit: Author

4.5 Significant findings related to Climate Change

As our cultural heritage sites are threatened due to climate change, preservation in the digital age demands for a development of new techniques. As we become increasingly aware of the coming devastation upon the built environment due to climate change, we must confront such challenges with realistic proposals for adaptation and mitigation for architectural heritage. The findings demonstrated through the experimentation in this article suggest that the use of Virtual Preservation methods and techniques could provide a viable solution to the mass physical loss of architectural heritage sites due to climate change by making full-scale digital experiences of a site’s physical counterpart before it is lost. While requiring a radical shift from current understandings and techniques within the field of preservation, the results from these experiments show that the user experience of such a digital experience holds a high pedagogical and experiential value with a high degree of
accuracy compared to their physical counterparts. Current technology developments suggest further that these methods will only become easier in the future.

4.6 Final Remarks

This study represents an initial, specific effort at evaluating the aforementioned hypothesis of the study. Further research and additional case studies must of course be performed in order to evaluate these possibilities further. However, the present results should document adequate evidence to propose that such methods be implemented into architectural heritage and preservation studies quickly in order to begin production of such Virtual experiences to a broad number of sites globally. And hopefully, this study will stimulate research funding into these areas further while contributing to international discourse. While several independent and state actors indeed are performing such studies currently, there lacks a broad consensus and understanding among preservationist and heritage experts regarding the mass loss of physical heritage sites due to climate change. This article therefore to have documented the viability and urgent need for such a discussion, in hope that such a disciplinary turn may soon take shape.

References


Towards a visual-based survey on explainable machine learning.

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Abstract | The increasing use of Machine Learning in people's everyday life raised the need for solutions aimed to reveal the work done by those models when transforming an input into an output. In the field of Computer Science, techniques of Explainable Machine Learning have been developed for unveiling algorithms' inner workings at different degrees of sophistication. The current status of the research on Machine Learning Explainability is still empowering the creators of those models but is not informing the people affected by them. Being information visualisation considered a good mean to show these processes, it is legitimate that tools able to help designers to browse visual models used in the past are designed. The paper proposes a visual-based methodology for displaying and analysing images in-groups as a support for designers in the observation, investigation and selection of visual models and solutions to be adopted in the area of Explainable Machine Learning.

KEYWORDS | INFORMATION DESIGN, VISUAL MODELS, EXPLAINABLE MACHINE LEARNING, DATA VISUALISATION, VISUAL DEVICE
1. Introduction

Explaining machine learning is the ability to present in understandable terms machine learning models to a human (Doshi-Velez & Kim, 2017). In the field of Computer Science, techniques of Explainable Machine Learning have been developed for unveiling and analysing algorithms’ inner workings at different degrees of sophistication. However, the current status of the research on Machine Learning Explainability is still empowering the creators of Machine Learning models but is not informing the people affected by these models (Correll, 2019). After a few years that Explainable Machine Learning techniques have emerged in the field of Computer Science (Lipton, 2016), the need to explain the internal functioning of Machine Learning algorithms has spread and amplified, starting to involve other fields, such as information design and ethics (Mittelstadt, Allo, Taddeo, Wachter, & Floridi, 2016). In the Computer Science field, different surveys (Garcia, Telea, Castro da Silva, Tørresen, & Dihl Comba, 2018; Hohman, Kahng, Pienta, & Chau, 2018) have been carried out to investigate and evaluate the state of the art and future research directions, especially for deep learning and neural networks techniques (Garcia et al., 2018; Hohman et al., 2018; Yu & Shi, 2018). Indeed, data visualization and visual analytics are considered good means (El-assady, Jentner, Kehlbeck, & Schlegel, 2019; Offert, 2017) for both communicating and explaining internal states of machine learning models. However, in the examined literature there does not seem to be a collection showing all the visual models used to represent processes regardless of the type of machine learning model.

The paper presents the initial phase of a research process that aims to investigate how information visualisation and design can be exploited to communicate to a lay audience the internal processes of machine learning algorithms that impact society. The presented stage of the research proposes a visual-based methodology for displaying and analysing groups of data visualisations as a support for designers in the observation, investigation and selection of visual models when dealing with machine learning explainability.

For distantly investigating the aesthetic patterns of visualisations in the field of explainable Machine Learning, in the paper, a method coming from the study of digital platforms has been used, leveraging tools from Digital Methods (Rogers, 2017). Digital Methods are a collection of tools and techniques that have been originally designed to analyze online text content with a sociological approach by experimenting on different online platforms — Twitter, Facebook, and Google —. Indeed, in the last years, the increasing dissemination of visual content on the web has driven the desire to develop techniques related to the study of images en groupe by using Digital Methods (Niederer & Colombo, 2019; Ricci, Colombo, Meunier, & Brilli, 2017). Most of the efforts have been made to study images from social networks and search engines to create networked images systems able to display multiple images connected by common attributes.

Since scientific articles, usually associated with images displaying visualisations and screenshots of interactive interfaces, are available on the web, this paper proposes an
Towards a visual-based survey on explainable machine learning

experimental approach for studying visual models in groups, for distantly investigating the aesthetic patterns of visualisations in the field of explainable machine learning by using techniques coming from the study of digital platforms (Pearce et al., 2018).

As machine learning spreads across domains, the aim is to draft a method that can help designers understand how visual patterns, colours, and shapes and other visual variables (Bertin, 1967) are used trying to visually foment and answer the question: How to visualise explainable machine learning process.

The intention of the paper is not to propose an alternative system for performing surveys, but to promote an integrative device that supports the exploration of case study collections and help information designers in browsing visual models during the design process.

In Section 2 related works will be presented, considering both existing surveys presenting explainable machine learning examples supported by visual analytics tools and image-based research; Section 3 presents a list summarising the design requirements; Section 4 describes the process that led from the construction of the dataset to the development of experimental visual devices; Section 5 briefly summarises results coming from the performed visual network analysis and in Section 6 strengths and weaknesses of the presented methodology are listed.

Being this ongoing research the result of an interdisciplinary approach to the study of aesthetics and visual patterns in the field of Interpretable Machine Learning, related works will be analysed by following both:

- surveys presented as tools for clarifying and systematising the state of the art on techniques and visual analytics for Interpretable Machine Learning. (Section 2.1)
- research carried out for analysing visual content (images) coming from the web presented in the form of networked images. (Section 2.2)

In the last two years, many surveys on Explainable Machine Learning techniques have been presented and discussed. Among these, some are specific to a group of machine learning models, while others differ by applying a more general approach. Moreover, examples of visual-based surveys coming from neighbouring areas will be taken into consideration.

2.1 Surveys on Explainable Machine Learning

While there is a substantial literature of surveys for visualisation and visual analytics applied in predictive analytics (Lu, Wang, Landis, & Maciejewski, 2018) and deep learning (Hohman et al., 2018; Yu & Shi, 2018) that takes into account: the reason why visualisation is used as a tool, the type of user to which it is addressed and in which context is visualisation applied, however, it seems that there is a gap in presenting a comprehensive and visual survey on visual models adopted in visual analytics for Explainable Machine Learning.
Often, evaluation grids and evaluation matrices (Garcia et al., 2018; Hohman et al., 2018; Lu, Garcia, Hansen, Gleich, & Maciejewski, 2017) are proposed as tools for browsing case studies and evaluation parameters can vary according to researchers’ own interests.

One of the most effective functional feature of evaluation matrices is that they provide a detailed and systematic vision ensuring a good exploration of contents, however, when it is necessary to list the visual models used to display explanations, they are presented through labels referring to visual model names (for instance “scatterplot”, “line chart” or “networks”) (left - Figure 1) together with screenshots of relevant use cases.

Surveys related to other fields propose diverse and interactive tools for browsing projects, Liu et al. (Liu et al., 2018) propose a comprehensive, interactive task-driven survey on text visualisation taking into account tasks, visual models and data mining techniques and how their use has changed over time. Unlike the latter, Kucher (Kucher, 2014) presents his ongoing, collaborative survey on text visualisation as an interactive browser that allows users to study and inspect research and projects by using a wide spectrum of filters that enhance the analytical process of the users.

Similarly, Isenberg et al. (Isenberg et al., 2017) are working on the Vispubdata project which provides free access to metadata and statistics on IEEE Visualization publications (IEEE VIS) from 1990-2018. From this repository, researchers can work on data and design tools for exploring them.

Figure 1. Two examples of evaluation matrices used for displaying case studies of visual analytics in deep learning. From the left: (Garcia et al., 2018; Hohman et al., 2018).
Nonetheless, as far as the literature related to explainable machine learning is concerned, the production of visual-driven survey methods seems to be still lacking.

The experiment presented in the paper provides a visual-based approach for collecting and displaying used visual models, proposing a method of representation, display and reading that departs from the evaluation matrix and the interactive browser proposed by Kutcher.

2.2 Visualising and analysing images en groupe

As mentioned in the Introduction, the described design approach leverages Digital Methods Tools. Although Digital Methods have been initially designed for allowing domain-experts in the field of STS (Science and Technology Studies) to investigate textual content on the web, in recent years they have been used also for analysing and exploring visual content — such as images and memes — coming from the web (Social Network, Online News, Search engines results).

According to the theory of composite images (Niederer & Colombo, 2019) observing relationships among digital images deals with the study of them en groupe and a recent approach for studying images en groupe refers to the use of existing metadata such as hashtag on Twitter or metadata attributed by Vision APIs Services as semantic tags. (Niederer & Colombo, 2019; Ricci et al., 2017) (Figure 3)

Vision APIs offer image content recognition based on predictions by returning a list of concepts with corresponding probabilities of how likely some concepts are contained within each image. (Figure 2)

When studying images en groupe, networks and networked images are the most adopted visual models (Ricci et al., 2017). This type of representations of contents allows researchers to conduct visual network analysis which focuses on the description of the network according to the topological distribution of nodes – images – in the space. (Pattern and cluster recognition, identification of bridging nodes, the relation between centre and periphery of the resulting network). (Venturini, Jacomy, & Pereira, 2016)
Figure 2. Vision API Service (Clarifai) results. Images are labeled with concepts according to their visual content. The confidence value shows how likely some concepts are contained within each image.

In declaring their limits and peculiarities, we used Clarifai (Clarifai Inc., 2013) a free Vision APIs Service for automatically tagging images of visualizations extracted from databases of peer-reviewed scientific articles — Scopus (Elsevier, 2004), Google Scholar (Google, 2004) and Web of Science (Clarivate Analytics, 1997) –.
3. Design Requirements

Part of the process of choosing the most appropriate visual model to represent machine learning models’ inner working is usually dictated by literature analysis, experimentation and evaluation.

The design of the tool was then guided by three points:

- **R1 - Visual-based approach:** Design a system able to provide information about the aesthetics and visual appearance of visualisation adopted for visualising Explaining Machine Learning processes.
- **R2 - A visual-based representation:** Design a method for visually representing a survey which differs from the evaluation matrix and the interactive browser.
- **R3 - A repeatable approach:** Design a system and a method that can be applied on similar conditions but referring to other (or filtered) data. (for instance, for analysing a specific group of machine learning models).
Final users involved are designers, whose aim is to provide new tools for explaining machine learning models’ inner workings, with an experience both in the field of design and in the field of computer science.

Below, the defined action to demonstrate the effectiveness of the methodology:

- **T1 - Pattern recognition**: Recognise cluster of contents and identify visual peculiarities.
- **T2 - Inference**: Inferring by exploring, annotating and browsing the visualisation which type of machine learning models are presented.

### 4. Methodology

The presented experiment has been carried on with the intention of ensuring its reproducibility, also thanks to the support of the protocol diagram (Figure 5) that, acting like a visual recipe, shows progressively each step needed to achieve the final visualization: from data gathering to final results. *(Design Requirement n° 3)*

#### 4.1 Data Gathering

Scientific articles have been gathered from three databases of peer-reviewed scientific articles (Scopus, Google Scholar and Web of Science) by using a consistent methodology. Each platform has been queried using “explainable machine learning” OR “interpretable machine learning” AND “visual analytics” and for each article the following information — if present — has been recorded:

- **Metadata** (title, authors, year, venue, link to the original document)
- **Images** including visualisations, illustrations, graphs, schemata.

While *Scopus* and *Web of Science* offer the possibility to perform advanced searches and download files in *.csv* format containing the aforementioned metadata (images excluded), for gathering data from *Google Scholar* the *WebScraper* (Magnetic Latvia, n.d.) an extension of *Google Chrome* has been used. Following this gathering process, a corpus of 238 articles has been obtained (82 results from *Google Scholar*, 96 results from *Scopus* and 60 results from *Web of Science*). Among these, only 6 papers are shared by all the three sources, 40 papers are shared by two of them and the remaining 192 are univocal.

By qualitatively browsing the results, emerged that some of these papers contain surveys and state of the art analysis, while others describe single case studies.

Then, scientific articles listed in the gathered surveys (Adadi & Berrada, 2018; Garcia et al., 2018; Hohman et al., 2018; Ming, 2017) have been added to the corpus and following this process a final collection of 257 scientific articles has been built.
However, not all the papers contained images, thus an additional filter was applied, allowing only papers containing images to be selected.

The final body of articles to be analysed contained a total amount of 194 documents whose pictures have been extracted using Adobe Reader. A final collection of 1059 images has been obtained. The final dataset is open source and available at this link.

4.2 Image tagging

Starting from the collection of images obtained through the qualitative and quantitative data gathering process, images have been tagged by Clarifai’s Vision APIs Service. Clarifai offers ready-to-use image recognition models which allow to recognize different classes of semantic content in images to suit researchers’ specific needs and, in declaring their limits and peculiarities, the general model has been tested being images contained in the corpus mainly visualisations and graphs. (An image recognition model for visual models and data visualisation has not yet been designed and would be the subject of further works).

To accelerate the process of image tagging, an interface\(^1\) of Clarifai API has been used. By uploading a .csv file containing the list of URLs referring to each single image of the corpus the interface output another .csv with the results of the predictive model on each image. As mentioned in Section 2.2, observing and representing relations among digital images is practiced by using networks and networked images. Moreover, generating image-keywords networks using descriptive tags provided by the vision APIs has become a common approach. Starting from the .csv output file a network where images are connected by the same descriptive tag has been generated (.gexf file) and visualised using the open-source software Gephi by setting ForceAtlas2 as spatialisation algorithm (Jacomy, Venturini, Heymann, & Bastian, 2014) and running modularity statistics to identify communities of nodes. Thanks to the Gephi’s ImagePreview plugin (Chrisxue815, 2019) nodes have been replaced with images and the network has been printed out on paper to be annotated with pens by data visualisation designers.

\(^{1}\) “This tool is an easier interface to the Clarifai API. What this API does in short is that it takes a list of images (in the form of URLs) and outputs what an algorithm, also called a model, sees in these images”
Figure 4. An example of visual network analysis performed by a designer on a network displaying images retrieved from a selection of the corpus.
Figure 5. The visual protocol explaining the methodology.
Figure 6: A bipartite network showing the relations among pictures and corresponding labels gathered from scientific articles filtered by tags whose confidence is greater than 0.98 (Figure 2). The network can be divided in two main areas: the right side where figurative models are grouped and the left side where chart and graph models are clustered (abstract models).

5. Results

The presented methodology has been tested on bipartite networks since they show connection between semantic tags and images. As the API module is not yet specifically designed to identify visual models, semantic tags are not very precise, however, it is possible to identify some clear clusters grouping similar visual models.

By observing the bipartite network (Figure 6) immediately emerges its bipolarity being the left-side populated by figurative visual models (pictures and saliency maps) while the right side is occupied by chart and graphs. Therefore, at first glance, emerges a central and generic cluster around the tag “no person” which is extremely generic, revealing the limits of the adopted vision APIs model but, at the same time, identifying a group of images to be tested with other vision APIs services. (Figure 7)
By looking more closely appears that the right side is populated by two well defined clusters: the first, on the top-right (Figure 7 and 8b) which mainly displays matrices that the Vision APIs Service recognised as calendar", "crosswords", while the latter, slightly below, (Figure 7 and 8a) contains charts and graphs.

Moving to the left side, even the cluster of t-SNe2 representation is evident (Figure 7 and 9a) where visual models containing “dots” are clustered. Instead, in Figure 9b which is located in the figurative side of the bipartite network, users can browse picture portraying animals and objects.

Moreover, the bipolar structure of the network also allows the observer to jump from one side to the other. For instance, users can see how the saliency maps cluster could be ideally
linked to the one related to graphical representations of neural networks on the top (Figure 6, circles connected by the straight line).

Figure 8: This is a zoom of Figure 6. On the left the group of bar charts and line charts. On the right, the cluster of matrices.

Figure 9: This is a zoom of Figure 6. On the left the group of t-SNe. On the right the cluster of animals.
6. Discussion

In this paper, we propose an experimental and interdisciplinary methodology for supporting designers in the action of browsing and choosing visual models through the presentation of a visual-based survey displaying images.

To our knowledge, this is the first attempt to design a data visualisation for showing metadata collections and images related to scientific publications.

The intention of the paper is not to propose an alternative system to the evaluation matrices seen in the literature but to promote an integrative device that supports the exploration of surveys and help designers in the choice of visual models. (R1).

A visual-based representation of contents (R2) helps designers in entering and integrating into the explainable machine learning field.

Moreover, the visual protocol allows designers to repeat the operation and apply the methodology even on other bibliographic collections. (R3)

However, we want to point out some weaknesses that may be addressed and fixed in the future.

- The paper selection has been carried out both qualitatively and quantitatively. Thus, the final corpus is subjective but what is relevant for this research is the methodology applied and its flexibility.
- The number of images for each scientific article is slightly different.
- The Vision API Service selected is biased too, the same process could be run on different APIs services (for instance: Google Vision APIs, Microsoft Azure, IBM Watson, Imagga) being their results potentially different. In the future could be interesting to design a training dataset able to identify visual models.
- The final networked images visual model could be interactive, allowing a dynamic browsing of contents and an augmented visual network analysis.

The presented organic and complete representations of visual models help designers in the act of browsing visual contents contained in scientific articles, and give the possibility to have, at first sight, an overall picture of the state of the art.

Moreover, visual network analysis helps in understanding relations between clusters and immediately identify relevant visual references in the design process.

6. References


Towards a visual-based survey on explainable machine learning


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Toys and Play, Weapons and Warfare:
Militarizing the Xbox Controller

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Abstract | In this paper I examine the cultural implications of the United States military's use of commercial video game controllers as contemporary battle equipment. My research draws on analysis of the academic literature on militarism and video games, controller studies, and media theory, as well as industry sources and mainstream media reporting. The paper is organized into three sections: a history of the relationship between the military and the video game industry, a discussion of the military's use of Xbox controllers, and an exploration of the causes and consequences of the increasingly blurry line between toys and weapons.

KEYWORDS | VIDEO GAMES, TOYS, PLAY, WEAPONS, MILITARY
1. Introduction

In 2017, the U.S. Navy made headlines for using Microsoft Xbox video game controllers to operate its newest submarines. Officials touted the ergonomic and cost savings advantages of the $30 off-the-shelf controllers compared to the clunky $38,000 helicopter-style sticks they used previously. They also cited a training advantage—crew members grew up playing Xbox and were able to teach themselves to use the controllers within minutes (Vergakis).

In this paper I examine the cultural implications of the United States military’s use of commercial video game controllers as contemporary battle equipment. My research draws on analysis of the academic literature on militarism and video games, controller studies, and media theory, as well as industry sources and mainstream media reporting. The paper is organized into three sections: a history of the relationship between the military and the video game industry, a discussion of the military’s use of Xbox controllers, and an exploration of the causes and consequences of the increasingly blurry line between toys and weapons.

2. The Military-Entertainment Complex

Some of the oldest games are war games. Go was invented more than 2,500 years ago. Chess is 1,500 years old. In the 1960s, with the advent of video games, the military took the lead in financing and developing the new technology, becoming the subject of games and sponsor of gaming technology. Spacewar! (1962), considered the first video game, was a war game developed by graduate students at MIT and funded by the Pentagon. In Joystick Nation, video game historian J.C. Herz notes:
“When you trace back the patents, it’s virtually impossible to find an arcade or console component that evolved in the absence of a Defense Department grant.” (Herz, 1997, p.205)

In the ensuing decades, game developers and the military joined in an informal cross-industry partnership known as the military-entertainment complex. They shared technological resources, recruits, and costs, and sought to standardize the visual style and play elements between war-themed video games and the military’s virtual training experiences. The military began applying video game technology and aesthetics to its own simulation trainings in the 1980s. A military think tank paid Atari to adapt its popular arcade game *Battlezone* (1980) for use as a gunnery trainer. In the 1990s, when the Defense Department’s game development capabilities fell behind the private sector’s, DoD began directly modifying off-the-shelf software for training purposes. The United States Marine Corps modified the popular first-person shooter *Doom II* (1994) to become the trainer known as *Marine Doom* (1997).

![Figure 2. Packaging for America’s Army: Rise of a Soldier for Xbox. Graphics include an image of a soldier in full battle gear, the U.S. Army logo, and the Teen rating symbol. Photo: qwertyuiop, mobygames.com.](image-url)
A high-water mark of this relationship was the release of *America’s Army* (2002), a shooter game developed and financed by the U.S. Army and distributed by free download. *America’s Army* was the brainchild of Colonel Casey Wardynski, who saw it as an opportunity to reconnect the army with popular culture and “youth decision space” (Wardynski quoted in Huntemann, 2010a, p.178). Wardynski recognized the power of video games to engage and educate young people: “It’s vivid, it’s active, you’re learning, you’re experience, you’re communicating” (Wardynski quoted in Huntemann, 2010a, pp.184–185). The game was a success, with more than five hundred thousand downloads in its first month. Console versions for Xbox and Sony Playstation followed in 2005. In 2007, the army opened the Virtual Army Experience, a giant, fully immersive version of the *America’s Army* game that toured air shows, amusement parks, NASCAR races, and music festivals. During the 2008 recession, recruitment rose, and the military stopped updating *America’s Army*. Though the game has faded, the military-entertainment complex continues. War-themed first person shooters dominate the market, and scholars have noted their structural similarity to the Global War on Terror—a perpetual war with unclear enemies, a constant state of alert, and endless replay (Huntemann, 2010b; Chien, 2010). The military has embraced new technologies like virtual and augmented reality for training, combat, and weapons prototyping. In 2019, the army launched a competitive e-sports team. The military’s use of Microsoft Xbox controllers, which began in the mid-2000s, is a crucial and under-examined feature of the military-entertainment complex. The paper’s next section focuses on it.

3. The Military and the Xbox Controller

3.1 Overview

The United States military and its contractors have been integrating Xbox controllers into battle equipment for more than a decade.
In 2007, technology bloggers noted the presence of Xbox 360 controllers in a photograph showcasing the army’s newest remote SUGVs (Small Unmanned Ground Vehicles). Part of the Army’s Future Combat Systems Initiative, the vehicles would allow ground troops to explore intense areas with minimal risk to life (Hickey). In 2008, WIRED magazine published a round-up of military use of video game equipment including a British army recruiting advertisement featuring troops using an Xbox 360 controller to pilot drones (Hambling). In 2014, WIRED reported that Boeing was building a laser cannon controlled by an Xbox 360 controller (Golson). The laser produced a beam of heat sufficient to disrupt rockets, artillery and mortar strikes, and drones. Evan Narcisse, covering the story for gaming website Kotaku, noted the irony that, “one could imagine conflicts where a 360 controller-steered laser will be shooting down drones piloted by the same input device.”

In 2017, the U.S. Navy began using Xbox 360 controllers to operate the photonic masts in its newest submarines. Each of these nuclear-powered vessels costs up to $2.7 billion dollars to manufacture and includes a number of cutting edge features (Knobeloch, 2018). Typical missile launch tubes have been replaced with two large-diameter payload tubes capable of launching six Tomahawk cruise missiles each. Sonar arrays are backed with water instead of air, resulting in a simplified, more cost-efficient mechanism. The Navy commissioned a custom joystick for the submarines, but soon abandoned it in favor of the Xbox controller (Vergakis).

For the military, the Xbox controller’s design offers significant benefits. Microsoft invested tens of millions of dollars into the ergonomics of the Xbox controllers, far more than the military would ever spend. Unlike the military’s clumsy, purpose-built joysticks, the commercial controllers are small, highly portable, and have limitless applications. The
controllers represent an enormous savings of money: $30 versus $38,000 for the original joystick. As discussed in the previous section, military use of video game technology is nothing new. The use of off-the-shelf hardware in battle equipment is simply a logical if dramatic extension of an established impulse.

Proponents of the military’s use of Xbox controllers favor terms like “instinctive,” “intuitive,” and “automatic” to describe soldiers’ adoption of the hardware (Schultz, 2014; Saletan, 2008; Singer, 2010). Indeed, in lab tests, sailors who would have required hours of training to use the submarine joystick taught themselves to use the controller in minutes (Vergakis). They were able to achieve this not because the controller’s 16-button, dual analogue console gamepad is easy to master, but because, having spent hundreds of hours playing with the controller as children, they had already mastered it. The sailors found the controller to be intuitive because of its familiarity, not its simplicity.

Maintaining that familiarity, even at the expense of functionality, appears to be an aspect of the military’s strategy in its use of Xbox controllers. The Xbox One, a more advanced version of the controller, was released in 2013, yet the military continues to use Xbox 360 controllers, which have been on the market since 2005. This departs from the military’s usual focus on cutting edge technology, favoring instead the more familiar, ubiquitous, even nostalgic option.

The military’s preference for the legacy controller reflects the general “counterrevolutionary” nature of console controller design, whereby Xbox’s base of hard core gamers threaten to revolt at the slightest update to its controller design (Parisi, 2015). Microsoft was so averse to jeopardizing its relationship with existing users that the Xbox One controller looks almost identical to the original, despite a $100 million investment in its redesign (Hsu, 2013). In fall 2020, Microsoft released the Xbox Series X console. Again, the controller design barely changed, “ensuring the muscle memory players have built up over the years remains intact” (Tuttle). This market-driven conservatism runs counter to persistent narratives projecting “revolutionary” technological change in the video game industry—and the military.

3.2 Survey of Scholarship

Critical study of the military-entertainment complex tends to focus on software. Despite its name, Joystick Soldiers (2010), an important scholarly collection exploring the relationship between modern warfare and video games, barely addresses controllers’ role in blurring the line between war and play. The book’s discussion of war games’ transition from analogue (board games) to digital (video games) focuses on changes in game play, cognition, and immersion, rather than material artifacts. Essays that consider the effects of screens on our understanding of war ignore the haptic in favor of the ocular. Scott Lukas’s piece on the relationship between virtual guns in games and real guns in the world hardly discusses the controller. This seems like a missed opportunity, given that the controller is the material object that enables the virtual fantasy.

This matches a general trend in the field of game studies, which tends to focus on software, not hardware. Standard controllers for standard consoles are particularly absent from
critical discourse. Viewed as “a constant of hardware” (Kirkpatrick, 2009), controllers are “seemingly immune from the fetishization of the new that has continually surrounded other types of game hardware” (Parisi, 2015). As the point of connection between player and game, the controller is indispensable to the act of play, yet forgotten in the act of play (Blomberg, 2018). The qualities that make controllers successful as design—stability, longevity, invisibility—largely remove them from consideration as objects of scholarly attention.

Since game studies offers a limited literature on controllers, other scholarly approaches must be considered. Perspectives from the study of media, digital culture, embodied interaction, and performance provide supplemental frameworks for consideration. These disciplines re-center the body in the gaming experience. Josh Smicker characterizes video games as “ensembles of technological and embodied performances” (2010, p.108). David Parisi understands gaming to be a process of bodily education and emphasizes the significance of haptic learning in game play:

“Learning does not happen only through the eyes and ears, but also in the fingers, hands, legs, and feet, and in the skin, muscles and joints.” (Parisi, 2009, p.112)

Irene Chien observes that players repeat battles “until attack movements become embedded in muscle memory” (2010, p.242). Simon Penny goes further, describing war games as software that trains the body to produce automatic reflexes instead of conscious interpretation and decision-making (2004). These scholars assert the importance of the body in video game play, and by inference, the importance of the controller, which functions as an extension of a player’s body (Crick, 2011).

4. Blurred Lines

4.1 Defining Terms

TOY: an object for a child to play with
WEAPON: an object designed or used for inflicting bodily harm or physical damage
TOY WEAPON: an object for a child to play with by pretending to inflict harm or damage

An Xbox video game console is a toy. Children star in its advertisements. Bright, primary colors feature on its iconic buttons. Upgrades and game launches are timed around the holidays to encourage gifting. But it’s a particular kind of toy. Because of its close association with popular shooter games like Halo, Xbox is also known as “Shooter Box.” Xbox serves as a bridge between military and commercial games. It was the first console to offer commercial versions of America’s Army and Full Spectrum Warrior. It’s the home of many other popular military-themed titles like Tom Clancy’s Rainbow Six series.

In 1928, Walter Benjamin defined toys as:

“Primitive technology combined with cruder materials imitating sophisticated technology combined with expensive materials.” (Benjamin, p.118)

Toy weapons fit Benjamin’s definition. They are cheaper, smaller versions of the real thing. They are intended to charge the imagination, not inflict harm. Does Xbox fit his definition? Not easily. Benjamin focuses on the form toys take—their imitative nature, their crudeness
relative to the real. Xbox games are imitative by nature of their virtuality, but Xbox technology is not primitive, its materials are not crude. Benjamin helps us differentiate a toy gun from a gun, and Nintendo’s Duck Hunt game, played with a light gun controller, from real duck hunting. But hard care gamers negatively review Nintendo for its ease of use and lighter subject matter—for being too toy-like (Payne, 2010). From what are we to differentiate Xbox? Its technology is more sophisticated, its materials are more refined, than many of the worlds it imitates.

Much attention is paid to the perceived dangers of toy weapons and violent video games. Though politicians and parents worry that these playthings encourage violent behavior among children, there is no scientific consensus on that. Children understand the difference between simulation and reality. They can differentiate pretend actions from real ones, toys from the objects they represent (Woolley and Ghossainy, 2013). They know that real guns are more powerful than toy guns: they can kill. Conversely, toy guns have virtual powers that real guns lack: They never run out of ammunition. They have perfect aim. People they “kill” can come back to life.

4.2 Causes of Blurring: Military Use of Video Games

Soldiers use video games at every stage of their journey through the military, from recruitment to training to treatment. These ludic acts, despite centering on engagement with virtual worlds, have real-world impacts. Rather than attempting to draw a line between real and virtual, it is more accurate to view the two as engaged in dialogue (Lukas, 2010), to acknowledge that gamers play “between worlds” (Taylor, 2006). In this way, the virtual bleeds into the real, and the real bleeds back. America’s Army is an example of the military’s use of games as a recruiting tool. The game was explicitly marketed to children and younger recruits, designed with mild violence and no swearing to ensure a Teen rating. Michael Zyda a USC professor who helped develop America’s Army recalled:

“Mothers would meet me and complain that ‘my son is playing America’s Army five to six hours a day, seven days a week. What is going to become of him?’ I would usually answer that these children would be twice as likely to consider a career in the US Army.” (Zyda, 2005, p.27)

America’s Army was hugely successful, netting more than 10 million registered users and a significant bump in recruits. The game—a virtual army—motivated people to join the real army. The modern military is increasingly reliant on video games as simulation training tools (Nichols, 2010). Jeffrey Leser and James Sterrett, former leaders of the Simulation Division at the U.S. Army Command & General Staff College, explained:

“Games create venues that allow students to learn from mistakes, building experience without the cost of combat.” (Leser & Sterrett, 2010, p.146)

Michael Macedonia, another simulation training leader, takes it a step further: “‘A lot of what we’re doing in [Army simulation] training is creating memories’ that can be recalled and triggered in combat.” (qtd. In Halter, 2006, p.198) Leser, Sterrett, and Macedonia deploy
the language of the actual—“building experience,” “creating memories,”—to describe virtual experiences.

Figure 4. Dr. Michael J. Roy, who oversees the "Virtual Iraq" exposure therapy at Walter Reed Army Medical Center, conducts a demonstration of a life-like simulator that represents a new form of post-traumatic stress disorder treatment with Army Sgt. Lenearo Ashford, Technical Services Branch, Uniformed Services University, on Sept. 16, 2008, in Washington, D.C. Photo: U.S. Army.

The military uses video games to treat soldiers when they are suffering from mental trauma. The USC Institute for Creative Technologies, the same group that produces many of the military’s training simulators, created the virtual reality simulator Virtual Iraq (2005). The simulator provides exposure therapy for veterans, placing them in a recreation of the world where they had a traumatic experience. According to Professor Skip Rizzo, who runs the project, “it helps the patient repeatedly confront and process very difficult emotional memories” (qtd. in Murgia, 2015).

4.3 Causes of Blurring: Technological Change
Advances in technology have further blurred the boundary between games and war. Changing approaches to television news coverage and video game content have altered the way civilians experience and understand war. Console-based video game technology has become less toy-like. The military is investing in new technologies that increasingly mediate and virtualize war.
Television coverage of the first Gulf War represented a turning point in the mediation of war. General Norman Schwarzkopf famously referred to it as the “first Nintendo war” (qtd. in Jenkins, 2003). 24/7 coverage brought the unremitting, yet highly mediated, violence happening in distant places directly into American homes. In this way, “our consumption or understanding or vision of battle [was] reduced to a series of images on screen” (King & Leonard, 2010, p.96). War-themed video games proliferated after the Gulf War, militarizing domestic spaces and normalizing global war. The online wargame Kuma War (2004), deliberately blurred the boundaries between fantasy and reality, mixing actual and fictional news clips with digital recreations, and offering just-in-time “ripped from the headlines” missions that allowed players to participate in real military battles right after or as they occurred (Smicrer, 2010). War, long understood by the American people to be a bodily horror, had become software.

In the decades since the first Gulf War, video game hardware and software have evolved along different paths: hardware has become more abstract and generic, while software has become more realistic and specific. Early consoles offered a range of specialized input devices besides the classic controller: light guns, steering wheels, and flight-sticks, even fishing rods and maracas. Xbox and PlayStation, today’s leading consoles, have converged on a similar all-in-one controller, with a complex combination of thumbsticks, d-pads, buttons, bumpers, and triggers. Its form is no longer a metaphor for anything but itself. As such, it does not conform to Benjamin’s definition of toy. Slipping the bounds of the virtual, it claims an unnamed space between worlds.

As controllers have become more abstract, the experiences they facilitate have become increasingly realistic. Today’s war-themed games are extremely vivid, with obsessively detailed sets, high fidelity weapons, and hyper-realistic audio and atmospheric effects (Lukas, 2010; Smicrer, 2010). Game producers, in partnership with the Department of Defense, aim to “transport players into spaces where the difference between virtual warfare and real-life military destruction is indistinguishable” (King & Leonard, 2010).

The military has been investing in new technology that increasingly mediates and virtualizes a soldier’s experience of war. For example, military contractor L3Harris is developing the ENVG-B (Enhanced Night Vision Goggle – Binocular), a heads-up display that augments reality with digital elements to enhance soldiers’ lethality in the battlefield. Cutting-edge thermal and night vision capabilities let them “see through dust and smoke” (South, 2019). A weapon-mounted camera allows them to see what their gun sees and shoot around corners or over barriers, completing the transformation of the soldier’s view into a simulation of a first person shooter game interface.

4.4 Consequences of Blurring

War-themed video games, despite their apparent realism, provide a sanitized version of war. Colonel Casey Wardynski, the mastermind behind America’s Army, claims, “We own realism” (Wardynski quoted in Huntemann, 2010a, p.184). America’s Army may provide a virtual replica of aspects of Army life, but it lacks anything resembling a realistic version of death. In
**America’s Army**, a player’s virtual death is noiseless, shown only by a small red circle, and followed by an immediate return to life (Nichols, 2010). Game producers, particularly those seeking a broader content rating, minimize the blood, carnage, and civilian death present in real combat (Nichols, 2010). As a result, war games are “cleaned up, void of horrific consequences, civilian casualties, and psychic devastation” (Huntemann, 2010b). Death may be a horror of war, but it is also a core mechanism of video games—to improve their play, gamers must die innumerable deaths. In *Virtuous War* (2001), security scholar James Der Derian asks whether virtual warfare’s erasure of carnage and bloodshed makes warring easier and thus peace more difficult.

Real war is not only bloodier than video games, it is more boring. War-themed shooter games tend to be structured around the experience of a soldier in the army’s Special Forces, an elite group that accounts for a mere 5% of the total armed forces. Most soldiers are more likely to be engaged in tedious paperwork than thrilling small-scale combat missions. The logics of most mainstream wargames cannot accommodate the tedium, anxiety, and trauma of combat, so they de-emphasize them by over-representing other aspects of war (Smicker, 2010). Stories that present a more nuanced picture of war are not completely absent from the gaming discourse. They show up in critical machinima movies like *Red vs. Blue: The Blood Gulch Chronicles*, indie games like Molleindustria’s *Unmanned*, and Hideo Kojima’s iconoclastic *Metal Gear* game series.

In the Global War on Terror, America’s most popular war-themed games serve as vehicles for ideology, expressing what foreign relations expert Walter Russell Mead calls “sweet power” (Mead, 2004). For example, World War II-themed shooter games like *Call of Duty* make a case for aggressive action in the Middle East by emphasizing “the greatness the United States can achieve through the use of military force” (Penney, 2010, p.201). Games sited in the Middle East, like *Conflict: Desert Storm*, alter real geographies to serve ideological ends. King and Leonard (2010) describe games that:

> “Construct and imagine places like Iraq and Afghanistan as barren wastelands devoid of civilians and infrastructure in need of saving and U.S. intervention.” (p.91)

Other games offer crude, culturally ignorant representations of “the other,” or force all players to assume the perspective of an American soldier (Leopard, 2010; Nieborg, 2010). In *America’s Digital Army: Games at Work and War* (2017), Robertson Allen notes that the *Conflict* series, celebrating the first Gulf War, was deliberately released during the period immediately surrounding the 2003 Iraq invasion.

### 4.5 Boundary Dissolved

**WEAPONIZED TOY:** an object designed for a child to play with, but used to inflict real bodily harm or physical damage

The military-entertainment complex, from *Spacewar!* to *America’s Army* to *Virtual Iraq*, is a sordid economy, feeding games with war and war with games. Compared to the frightful promise of new technologies like the ENVG-B, the military’s use of Xbox 360 controllers might seem innocuous. After all, Xbox has no advanced weapons system. It’s a mainstay of
dens and dorm rooms, representing camaraderie and competition. On the contrary, the Xbox controller’s seeming innocence is the key to its danger—its use by the military represents the final dissolution of the fragile boundary separating toy from weapon and game from war.

The military’s reasons for using the controllers are eminently practical. Soldiers are already highly skilled users. The cost savings are tremendous. The technology’s ergonomics, design, and functionality are better than anything the military could create (Vergakis, 2017). The Xbox controller is all these things. It is also a designed object that operates in a complex web of associations that precede and inflect its use by the soldiers who fight America’s wars. In *Discursive Design* (2018) Bruce and Stephanie Tharp explain the significance of designed objects:

“Designed objects are never semantically sterile or ideologically inert; they are always inscribed—intentionally or unintentionally—with meanings and values of the cultures that produced them and the cultures in which they eventually exist or are consumed.”

(p.10)

The Xbox controller was designed to be a toy, an object for a child to play with. Video game systems like Xbox are an integral part of millions of American homes, routines, and relationships. A central source of entertainment, friendship, competition, and learning, video games are “woven into the fabric of contemporary existence” (Huntemann, 2010b, p.242).

The Xbox controller is “intuitive” to soldiers because it is a beloved childhood toy. Soldiers “automatically” know how to use it because they have spent hundreds of hours cradling it in their hands, and associate it with embodied memories of play (Parisi, 2015).

The Xbox controller was also designed to disappear. As in Mark Wigley’s description of the computer mouse, “its relentless smoothness in shape and frictionless movement...fuse the gap between human and machine” (2010, p.50). The controller’s constancy renders it nearly invisible—the skilled gamer must forget the controller’s presence to immerse in play (Parisi, 2015; Blomberg, 2018). It also disappears by deflecting attention. Unlike a mimetic controller, it doesn’t look like a weapon. Unlike a motion-tracked controller, its use doesn’t require violent or aggressive movements (Parisi, 2009).

5. Conclusion

Ultimately, the military’s reasons for repurposing the controllers are a smoke screen. Soldiers can be trained. The cost savings are a tiny fraction of the overall cost of a nuclear submarine. The Xbox is unnecessarily sophisticated for the military’s purposes.

By virtue of its status as a designed object, the Xbox controller is inscribed with far more consequential meanings and values than the military acknowledges. In a chilling echo of the simulator that turns out to be real in Orson Scott Card’s science fiction novel *Ender’s Game*, the military is cynically tapping a beloved object from the childhood of the gamer generation, and repurposing it for the American war machine.
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Wearing the smart city: Supporting older adults to exercise by combining age-friendly environments and tailored digital public data

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Abstract | In response to the call on supporting aging populations, this research focused on wearable health technology. Semi-structured interviews were conducted with eight older adults who were using wearable devices to self-manage their health. Three thematic frames were applied to analyse transcripts focusing on emotional, quality and functional goals that users would like to experience during technology use. It was found that participants wanted to feel motivated when using the technology. In addition to being a reference point, they wanted the wearable to support the management of their health. While the potential design for future wearable devices can consider these goals, the built environment can present barriers in achieving them. It is argued that more research needs to take place to better understand how the holistic goals of older adults when using wearable devices in their neighbourhood can be reinforced by the urban environment. By doing so, insights into strategic development for the design of age friendlier cities can be gained.

KEYWORDS | WEARABLE HEALTH TECHNOLOGY, AGE FRIENDLY CITIES, HEALTH SELF-MANAGEMENT, URBAN AGEING, MOTIVATIONAL MODELLING.
1. Introduction

It is widely known that the world’s population is ageing and will continue to grow at an unprecedented rate. According to the World Health Organisation (WHO), the proportion of the global population aged 60 will double from 11% in 2006 to 22% by 2050 (WHO, 2012). In Australia, in 2017, 15% of Australia’s population of 25.3m million people were over 65 years of age. By 2047, this proportion is projected to increase to 22%. As Australia’s current population of 65-year-olds can expect to live on average another 21 years, there will be proportionally more ‘older-old’ adults >85 years (Australian Institute of Health and Welfare, 2020).

Due to the global trend of population ageing, there has been great emphasis placed on ‘healthy ageing’, which is defined as a lifelong process of optimising opportunities for improving and preserving health and physical, social and mental wellness, independence, quality of life and enhancing successful life-course transitions (Health Canada, 2002). In particular, an urgent need has been highlighted to develop strategies to ensure that older people enjoy life in their years and not just extra years in their life (Alley, Liebig, Pynoos, Banerjee, & Choi, 2007). This gives rise to the question of how we can better support the parameters of healthy ageing.

In response to this question, the WHO developed the concept of ‘age-friendly cities’ to optimise opportunities for preserving and improving wellness and quality of life. As identified by Alley and colleagues (2017), age-friendly cities should ideally provide a supportive environment, enabling residents to grow older actively within their families, neighbourhoods, and civic society and present opportunities for their participation in the community. To assist with the implementation of age-friendly cities, the WHO gathered representatives from 22 countries with the aim of determining key elements of the urban environment which can assist with active and healthy ageing. This resulted in a framework for assessing the “age friendliness” of a city and included eight domains of city life: 1. outdoor spaces and buildings; 2. transportation; 3. housing; 4. social participation; 5. respect and social inclusion; 6. civic participation and employment; 7. communication and information; and 8. community support and health services (WHO, 2009).

The convergences of ageing, residing within cities, and age-friendliness, are rapidly producing new modalities to better identify the challenges, such as the notion of ‘urban ageing’, defined as the population of older people living in cities (Van Hoof, Kazak, Perek-Bialas, & Peek, 2018). Such challenges include the creation of inclusive neighbourhoods and the implementation of technology for ageing-in-place and independent living.

According to Kestens and colleagues (2016), few studies have considered older adults’ daily mobility to better understand how local urban and social environments may contribute to healthy aging. However, one way in which a better understanding can be gained is through the use of wearable sensors and software applications as they can offer novel means for gathering information on mobility and levels of physical activity (Kestens et al., 2016).
Wearing the smart city: Supporting older adults to exercise by combining age-friendly environments and tailored digital public data

Smart health technologies are increasingly being considered as supporting interventions in dealing with some of the challenges associated with urban ageing. In line with Kestens and colleagues (2016), the use of wearable devices in the support and management of independent older adults is becoming more widely advocated (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017) and a growing number of seniors are using wearable devices to self-monitor and manage their health (McMahon et al., 2016). In this context, we define wearable devices as those that can be “worn or mated with human skin to continuously and closely monitor an individual’s activities, without interrupting or limiting the user’s motions.” (Gao et al., 2016, p. 509).

To maximise the uptake of such devices, we argue that more research needs to take place in order to better understand the functional, quality and emotional goals of older adults when using wearable technology to maximum benefit within their urban environment. Collectively, these goals form the basis of motivational modelling which not only focuses upon the functionality of designed solutions, such as what technology should do, but also considers the social context in which technology is being used. As such, by also modelling the quality goals (i.e., how the technology should be) and the emotional goals (i.e., how it should feel), the holistic needs of the end users can be identified which will enable the development of socio-technical systems that support people in their everyday lives (Miller, Pedell, Sterling, Vetere, & Howard, 2012).

2. Method

2.1 Participant Interviews

Forming part of a larger study, this study involved a total of eight older adults who were aged 55 years or older who are using wearable device(s) to self-manage or self-monitor their health (Borda et al., 2018). Semi-structured interviews were conducted with participants via Skype, phone and/or email. Interview questions were centred around participant experiences and aspirations towards self-management of health using wearable devices. While a guideline was used with key questions to ensure comparability the format allowed the participants to guide the conversation and to express their opinions, and tell stories in relation to the use of the technology (Wengraf, 2001). The questions included: How long have you used a wearable device(s) to monitor your health? Can you tell me a bit more about when and why you started using the device? What was the motivation? Will your future ‘healthy self’ include wearable devices? Each interview took approximately 60 minutes to complete. All data was audio-recorded and transcribed into Microsoft Word documents. The research received approval by the University of Melbourne Human Research Ethics Committee (Ethics ID: 1646991.1).
2.2 Data analysis
A content analysis of interview transcripts was conducted. Content analysis enables researchers to go through a large volume of gathered data, from identifying key themes to emerging patterns (Cavanagh, 1997). Patton (2002) suggests that “content analysis is used to refer to any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings” (p. 453). Themes were extracted and categorised according to the perceived value of the different goal categories. Hence, the analysis was done through the lens of the three thematic frames. These frames are the individual user emotions (i.e., how the wearable technology should feel), the qualities of the wearable technology (i.e., what the wearable technology should be) and the functional aspects of the wearable technology (i.e., what the wearable technology should do). This approach is known as motivational goal modelling and the notation of functional and quality goals has been developed by (Sterling & Taveter (2009). The focus on emotional goals has been added by Marshall (2014).

In order to increase the credibility of the qualitative data analysis and ensure a high level of commonality for the interpretations made, several researchers (authors of the paper) analysed the data (investigator triangulation) (Guion, Diekl, & McDonald, 2011) and themes were confirmed when shared by the analysing researchers.

3. Findings
3.1 The individual user emotions
A common emotion experienced across all users was a feeling of motivation afforded by the wearable health technologies. This finding aligns with comparable studies (e.g., Kononova et al., 2019). Here, motivation was described by participants as the core driver to use their technology. For example, one participant described their ‘Fitbit’ device as the motivator to reach a certain number of steps each day. Here, they shared their thoughts about wearable technology as a motivator.

“I think it's the motivation. I think it created this thing for me it was the motivation to make sure that pedometer showed a lot of steps at the end of the day”.

Another participant described how the presence of the device motivated them to get up from their desk and go for a walk.

“I just wanted to get a little bit more active. I work in an office. A semi sedentary job and I've found it encouraging me to get up from a desk and walk around to get my steps up. And if I was wearing one, I would be conscious that I had it on and therefore I'd be more conscious of getting up and doing something and being active”.
3.2 The qualities of wearable health technology

While a feeling of motivation was expressed as a core emotion when using wearable health technology, participants described the technology as being a reference point or providing feedback of their participation in exercise which attributed to their motivation. For example:

“And then I found that I’d be sitting there till 10:00 or 11:00 in the morning doing some work. And then I realized I'd only done a thousand steps tonight and that would horrify me. So, I'd be out there and make sure if I had a class or lunch time, I did some activity after work and I was much more motivated knowing that I was needing to do more activity.”

An awareness about reaching ten thousand steps each day motivated the participants to exercise. Here, one participant described how they use their wearable device to monitor their steps progress.

“It was more just to monitor my level of physical activity and because I was aware of the you know the guidelines for 10,000 steps a day and all that sort of stuff”.

It is common that emotional and quality goals complement each other. Here the quality of being a reference point was often related to the motivation – the feeling of achieving a certain amount of steps.

3.3 The functions of wearable health technology

The primary functional aspects for which participants described their wearable health technology is to manage their health. Managing one’s health ranged from gaining insight into sleeping behaviours, blood pressure, weight and pain. For example:

“First [goal] was weight loss. I understood that making 10,000 steps a day is you know – that will help keep you healthy and lose some weight” and,

“I've had a flare up of rheumatoid arthritis in the last month, so I haven't been doing those things. So, it’s that means that the Fitbit and steps is sort of at the top of my aim each week”.

Again there is a relationship between the functional goal and the other two goal categories. The information a person desires and requires to manage their individual health has an influence on the reference points and the motivation experienced.

3.4 Wearable health technology and the urban environment

Several participants directly discussed their interactions with the urban environment. This took various forms. For example, the use of wearable health technology was a motivator for more city walking.

“If we don't have much on and we need to go into the city my husband and I will walk into the city so that is 3.5 kilometres. You know I just like to record that”.

Wearing the smart city: Supporting older adults to exercise by combining age-friendly environments and tailored digital public data
In two cases wearable health technology was a motivator in urban mobility in combination with other interventions, for example.

“The minimum exercise I have every day is walking to the bus stop and I get off the bus a few stops early and walk up the back streets to the hospital. And that’s even more now because of the changes with the roadworks. Sometimes I’ll get the bus in the morning and walk home at night. I just have to monitor how my hip [is doing] and bailout if it’s not up to it”.

“And it was an alarm that went off telling me you know you have to... And so when it comes to the number of steps, I still take them. But I had to get a dog to make sure that I did those numbers. ... So, I took a dog; a living creature to help me make my steps”.

In a unique case, one participant who took part in the study from outside Australia (Sweden) became increasingly involved in the use of multiple wearable health devices for health self-management, including the use of a chip implanted in his hand. The latter enabled the participant to engage in a smart city scenario.

“We use it in our office to open doors and get the printers running and I can use it when I check in to the gym. I can use it when I travel by Swedish railroad. The railroad company can read the chip with their Android phones.”

The motivational goals in this case are also tempered by emotional ones, perhaps, due to the uncommon nature of the adoption of the technology.

“I have it [the chip] in my hand. So that’s sort of a real -you know -a discussion starter. Half of the people – no, one third say "oh that’s terrible". I would never do that. And it’s really very emotional. It’s not like you know they thought about the pros and cons”.

4. Discussion

A content analysis of interview transcripts was conducted through the lens of three thematic frames. The first frame was user emotions; all participants reported the wearable technology motivated them to exercise each day. The second frame was qualities; the wearable technology was a reference point which gave them a competitive edge to reach guidelines for 10,000 steps per day. The third frame was functionality; the wearable technology allowed participants to manage their health, such as maintaining a healthy weight. These frames form the basis of motivational modelling by which the holistic needs of the end-user are identified, enabling the development of products, systems and services to better support people in their everyday lives (Miller et al., 2012).

However, while the potential design for future wearable health technologies can consider the emotional, quality and functional needs, the environment in which older people experience these attributes is paramount (Ehn et al., 2019). For example, consider an older
person who requires access to public toilets. Their motivation to walk may be present but following through with the action (of walking) may be limited in environments where there are few public toilets. Likewise, consider an older person who would like to rest under shaded areas on a sunny day. Using their wearable device as a reference point to compare how many steps they did for the day before becomes impractical because again, they are unlikely to go for a walk within environments where shaded areas are scarce. Within the present study context, the emotional, quality and functional goals become obsolete when there are environmental barriers within the community, resulting in activity goals unable to be achieved. Supporting studies have shown that safe, walkable, and aesthetically designed neighbourhoods, with access to specific destinations and services positively influenced older adults’ physical activity participation (Barnett et al., 2018).

As acknowledged by WHO (2007), “active ageing depends on a variety of influences or determinants that surround individuals, families and nations. They include material conditions as well as social factors that affect individual types of behaviour and feelings” (p. 5). Hence, there are an array of factors, and interactions between them, that can play a pivotal role in determining how well people age.

In line with the ‘age friendly’ cities framework in which outdoor spaces and buildings were identified as a domain of city life and which can assist with active and healthy ageing, it is argued that there is a clear need for public infrastructure data sets. Specifically, if a digital city layer showing, for example where facilities such as public toilets, water fountains and shaded rest stops were located on exercise routes in communities, it is possible that this would support older people in achieving their exercise goals. Ultimately, it could also optimise opportunities for preserving and improving wellness and quality of life. This public infrastructure data could be available as an app which would allow older people to download directly to their smart wearable device and customise the information, depending on where they are located and their preferences to show the information needed (Kestens et al., 2016; Cuignet et al., 2020). Given the continual advancements in wearable technology, the ability to tailor this information for each older person and integrate this information in an easy to understand way on their smart device is achievable. However, this means that the digital information layer about the environment needs to exist and can connect to the wearable device. Here we argue that in the context of age-friendly cities, there is a need to connect to the smart city discussion by breaking up silos of technology, the environment and human-centred design. In putting forward the goals of different user groups, in our case older adults, we acknowledge the existence of different needs and how they can be accomplished through knowledge about the environment. This data can not only inform the user about the best route to take in order to achieve their goals but can also feed back into city planning for shaping these environments. Given that wearable devices are increasingly being used by older adults, it is important to take the next step to connect environment, technology and the user to create a holistic system that supports the quality of life of an ageing person. For a more detailed discussion on opportunities of informing ‘age friendly’
cities through combining digital, social and physical data according to the WHO framework please refer to Pedell et al. (2021).

5. Limitations

The present study was not intended to provide a comprehensive approach to understanding the use of smart wearable devices by older adults but rather, an exploratory one that highlights the opportunities in considering the potential relationship of urban environmental factors within a digital health and urban ageing context. This ‘lens’ has inevitably considered that there are also differing definitional boundaries across individual preferences, health technologies and determinants of health/multi-morbidities, which require a larger cohort to determine the extent and measures of correlates. Visual analyses would further provide a means to examine urban and geolocative features in more detail, giving rise to the possibility of providing more guidance for age-friendly city and neighbourhood strategies.

6. Conclusion

We suggest a convergence of motivational goal modelling and public infrastructure data sets that are conducive to age friendly cities. At this convergence, wearable health technology can be designed to support journey plans that present public infrastructure and that can enable individuals to participate, complete and reach walking goals or step targets. At the core of our research, we advocate for a digital city layer that can be accessed and individually tailored by older wearable health technology device users. By doing so, uptake and acceptance of wearable health technology devices by older adults may increase, leading to enhanced wellbeing. Insights into framework development for the design of age friendlier cities may also be gained.

7. References


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