# Human Body Interaction

edited by Michele Zannoni, Roberto Montanari

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# Summary

# INTRODUCTION

This book was born from the *Human Body Interaction* research begun in 2020 and performed by the Advanced Design Unit at the Department of Architecture of the Alma Mater Studiorum - University of Bologna in a partnership with the company RE:Lab. The research is investigating how the pervasive spread of new technology is creating an unprecedented awareness that takes shape in deep body manipulation practices and processes through design.

The research process branched from the book *Human Body Design: Corpo e progetto nell'economia della trasformatività* by Flaviano Celaschi and Giorgio Casoni, published in 2020. The essay intertwines experience and knowledge from different disciplines in an attempt to analyze human beings by underlining their need and ability to design human beings. It investigates how and why we have become who we are and how we continue to transform a little at a time.

An international symposium has taken place on June 22, 2021, during this analytical phase. The symposium was called *Future Design for Human Body Interaction* and was organized by Michele Zannoni and Roberto Montanari with the help of Giorgio Dall'Osso and Marco Pezzi. It aims to investigate how enabling technologies are creating skills and behaviors with which new innovation processes take place to deeply renew the concept of design for the body. The Symposium was the occasion to discuss – online and in a multidirectional manner – several questions related to the evolving human-machine relationship.

This book has been created to summarize three years of scientific reflection that has contributed to developing research on contemporary design transformations and how such new design methods are finding a deep exchange with the human as a whole – mind and body.

The project was subdivided into three phases: shared analysis of the state-of-the-art; a debate through the symposium; and an active phase to create promotion tools. Phase 1 results have produced the design trends and trajectories that have brought numerous international guests to the symposium. We collected the presentations by the latter in this book.

Interaction with one's body is a natural human process since the dawn of time. It has found expression in multiple functional and social actions that have changed the use of the body, transforming features and allocating specific functions and processes to specific parts.

The great design challenge began at the end of World War II and was related to the development of Alan Turing's computation machine and Norbert Wiener's retroactive principle applied to cybernetics. It deeply affected the interaction between man and artifact through a new form of communication with machines in which the control system interface became a "colloquial" artifact as defined by the semiologist Giovanni Anceschi in the early-1900s.

Technology and the human body have intertwined in numerous critical mutation rates over the centuries. The overcoming of the limits of the human envelope was only allowed in medical sciences, but in time, technology has come to lean on the body, embracing its information and building new forms of biunivocal communication in which the physical limits have oftentimes been manipulated and weakened, becoming secondary in the design process.

The body has developed through physical and intangible extensions that led it to communicate with machines in a natural manner. In this scenario, the topic of the interface has become a cornerstone of the design process, with the concept of the prosthesis being gradually abandoned in favor of the creation of functional and relational attachments. Today, humans and their bodies may be considered partially connected through the complementary objects we have created and that constantly generate data that can be used for personal or collective purposes and at the service of the individual or community.

Given these premises, the book has been organized into four sections: Human Body Design and new interaction scenarios, Human bodies, digital, and virtuality; Human bodies, systems, and machine interaction; Human bodies, digital data, and social impacts.

The first section begins with a general subsection on **Human Body Design and new interaction scenarios**, which includes essays by the two main authors of the book: *The human body is the interface* by Michele Zannoni and *Haptic technologies for sensory and sensation design* by Roberto Montanari with Annalisa Mombelli and Arianna Fantesini, which summarize the research topics by underlining the transformation processes in the physical and cognitive interaction between humans and artifacts.

The section also includes two texts dedicated to the Human Body Interaction research edited by the specific workgroup and describing the International Symposium of Future Design for Human Body Interaction along with the database of case studies resulting from the same.

Three contributions complete the section: *Haptic microinteractions, silent details in human-space interaction* by Giorgio Dall'Osso and Marco Pezzi, *Design of the human body: From fiction to reality* by Andreas Sicklinger and Mirko Danieluzzo, and *Towards a responsible perspective in design for Human Body Interaction* by Elena Formia. Such texts contextualize the research scenario through three key aspects: changes in tactile interaction with the interfaces in relation to the growing physical responsiveness of digital elements; the relationship between human beings and ergonomics, as well as their transformations concerning the evolving concept of cyborg; a historical-critical retrospective of the theoretical contributions that have anticipated Human Body Design research in time.

The second section of the book – **Human bodies, digital, and virtuality** – introduces a crucial topic of the design and digital worlds in two main connotations: one related to the dematerialization of experiences in virtual spaces; and one related to the importance of tracking feelings in design processes. The essay *Human in digital: Mind and body grappling with project-making in a dematerialized world* by Flaviano Celaschi, Francesca Bonetti, Giorgio Casoni, and Alberto Calleo, along with *Virtual dance for real people. Dancing body and digital technologies: Presence or absence of bodies?* by Annalisa Mombelli and Fabio Ferretti offer a reflection on the topic of the lack of a tangible human body dimension.

The text *Emotions as a driving force for the design of future products and services* by Maura Mengoni, Silvia Ceccacci, Luca

Giraldi, and Roberto Montanari deals with the theme of tracking emotions and paves the way for novel frameworks of Human-Machine interaction in which the feeling-recognition processes contribute to developing new possible products able to understand people and adapt accordingly.

The essay by Elena Vai *Culture and creativity in incorporeal cities. Designing collective creative bodies* completes the section by stimulating a reflection on cultural creative industries and Human Body Design concepts.

The third section – **Human bodies and system and machine interaction** – opens with the text *AI Interaction scenarios for Human Body Design* by Andrea Cattabriga: a review of the design technologies and opportunities of AI instruments. Successively, Alessandro Pollini, Sebastiano Bagnara, and Angela Di Massa present an analysis of *The evolution of the HMI design* in the industrial context, which sheds a light on the need for the sector to develop its tools in relation to humans and the transformations that technology is generating in everyday life.

Both *Driving ahead - Some human factors issues related to future connected and autonomous vehicles* by Andrew Morris, Chris Wilson, Rachel Ma and Pete Thomas and *Understanding and exploiting the driver's state within the in-car environment* by Roberta Presta, Silvia Chiesa, and Chiara Tancredi investigate the automotive field, revealing the new design scenarios that the self-driving processes are introducing to this area of the project.

The book is completed by the **Human bodies, digital data, and social impacts** section, whose contributions investigate the relationship between the body, data, and social aspects related to local contexts. It begins with the essays *Wearables and self-tracking: A design perspective on personal data* by Pietro Costa and Luca Casarotto, and *Wear and aware: Citizens, sensors, and data to design inclusive research processes* by Margherita Ascari, Valentina Gianfrate, and Ami Licaj. The texts analyze the topic of data creation and use, investigating the individual's private and collective sphere.

In conclusion, *Human-centered technologies for a more senior-friendly society* by Giuseppe Mincolelli, Silvia Imbesi and Gian Andrea Giacobone describes three projects in which technology has been designed to cater to the needs of senior citizens.

This book has attempted to spur a debate through ongoing projects and research focused on the topic of Human Body Interaction expressed in the three research fields: *Homo faber* (Humans and their constructive actions), *Homo saluber* (Humans in a system of wellbeing), and *Homo cogitans* (Humans between interpretation and prediction).

It has emerged how the design of artifacts and interfaces continues, to this day, to involve the human body in search of rules, balance, and efficiency. Objects are designed with the ambition to safeguard the physical nature and mind of individuals in their private and collective spheres in order to promote quality and effectiveness in the performance of actions related to new digital technologies.

Ergonomics issues are changing radically: we have seen a shift from design for usability to the design of and experience/ customization of artifacts based on individual bodies. There has been a transition from interfaces as instruments of mediation between people and technology to the design of growingly adaptive and responsive wearable devices. The data interpretation of the latter introduces new design scenarios in a balance between the search for wellness and new human experiences.

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# HUMAN BODIES DESIGN AND NEW INTERACTION SCENARIOS

# THE HUMAN BODY IS THE INTERFACE

*Michele Zannoni**

In the interaction design fields, we have often considered the interface a tool between the human body and another entity, regardless of whether the entity is another living organism, an object, a machine, or a system.

In the Italian context I have trained in, the form of the interface has been – for many years – a topic of discussion that has seen different points of view (Anceschi, 1993; Bonsiepe, 1995; Maldonado, 1997; Bagnara & Pozzi, 2011) but now more than ever, this design context – understood as a control instrument for something external to our body – is dissolving and vanishing into the artifacts, just like the concept of machine or computer is slowly becoming physically and culturally invisible (Norman, 1998). Sebastiano Bagnara and Simone Pozzi (2011) had already envisaged this moment of transformation in the past, but the reflection I present today as a conclusion of a years-long research path leads me to claim that the design discussion on the body has returned to the front stage, and the artifacts we identify in our sector as *interfaces* are gradually integrating with the same.

This design scenario is not a recent event but has already been the subject of multiple experimentations in art and media studies in the past. The exhaustingly quoted claim by Marshall McLuhan, who stated that even media may be considered an extension of man (1964), helps us understand how relationship and communication tools may be a single entity composed of mind, body, and interface. About this position, considering the contemporary technological debate and keeping in mind that most adults in the more developed countries daily use a smartphone to communicate and connect to the web, it is fair to claim that such devices are also extensions of our bodies we cannot do without if we wish to relate to the system we live in.

This symbiosis in the communication system becomes evident from the moment we culturally *hooked up* to the web and its servic-

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es that sped up long-distance communication (Bauman, 2000) and demanded a part of our brain to focus on such devices (Flusser, 1990; Bannon, 2006; Bagnara, 2006; Zannoni, 2018).

To assert the above, I believe it is necessary to review – through several analyses – some of the innovation processes emerging in the past few years in the Human Body Design context, defining as a problematic field the technological implications that growingly contaminate the artifacts and the forms of interaction that humans may adopt in using them.

In this reasoning, it is not simple to set a limit and classify the designs currently identified as wearable devices, but it is important to consider how these may be, first of all, the result of a gradual size reduction of existing objects external to the boundaries of the body. We may, instead, identify a second class of designs born, in relation to the human and the body itself and configured as prostheses (Maldonado, 1997). This second kind of object is a quite promising design path in which innovation processes are forming new scenarios where the body may integrate daily and harmonically with such instruments.

## The instruments of humans

If we reconstruct the steps that humans have taken to design their instruments, a meaningful reflection on the design implications on the body and its artifacts has emerged in anthropological research. We have acknowledged that in terms of the construction of everyday interface tools, the signs of humans' approach to the construction of artifacts with a focus on ergonomic demands already existed in ancient times. The relationship between humans and tools was primary, and the units of measure were based on the body itself. The transformation of the being into *Homo faber* – a craftsman who uses tools and machines – was a fundamental moment when humans separated from his instruments and placed them in a workplace (Marchis, 2005, p. 6). The relationship with machines that took shape over the centuries mutated and definitively matured in the Fordist age, becoming a process of mechanization whereby the machine helps humans in high-precision operations and amplifies their strength. In the mid-1900s, following several experiments including Alan Turing's research on mechanical intelligence (Turing

& Ince, 1992) and Norbert Wiener's work on Cybernetics (1948), the age of automation reached a maturity in which machines control themselves by running programs defined by man. This operational ability – derived from the increase in the computational force of machines and the progressive evolution of sensors – would pave the way to mass production and the definitive loss of the relationship between the body and the act of production. In the first twenty years of the 21st century we are witnessing, instead, a gradual inversion of the human-machine relationship that is defined *heteromation* (Ekbia & Nardi, 2014): a different relationship where it is the human being that helps the IT instrument perform its tasks through choice processes that cannot be automated. These simple, everyday actions applied by humans to digital systems are a set of small, invisible activities – such as choices made online – supporting an Artificial Intelligence that needs to learn to act independently.

US anthropologist Levis Mumford (1967) – and, later, Flaviano Celaschi (2016) – stated that in their evolution, humans have constantly transformed their bodies to adapt to their environment. They improved the specialization of their upper limbs, using them more and more for high-precision actions compared to the lower limbs, which were dedicated to motion. This attitude was then conveyed to objects, with the first forms of prostheses, where clothing was added to the skin and tools were added to the upper limbs.

This process has never stopped. If, on one hand, we may consider these elements as systems of protection from the environment, we may underline, on the other hand, a continuous tendency to shift the primary functions of our social, communication, and working lives to the body in a new form of digital nomadism (Rifkin, 2000, p. 43; Saffer, 2006, p. 213; Zannoni, 2018, p. 74).

## New and ancient human anthropologies

In humans' physical, social, cultural, and artistic transformation, we face multiple anthropologies that define them and describe their facets – for instance, in opposition to the figure of *Homo faber* we may consider the other component of human nature identified as *Homo ludens* by Johan Huizinga (1938) in his 1930s treatise establishing the theoretical and philosophical foundations of the role of play in the sphere of human relationship systems.

The human dimension of the playing man and the productive man show us two systems of interaction that in their often antagonistic nature involve human existence in a constant challenge – on one hand against the environment that we emancipate from through artifacts and, on the other hand, against ourselves and others whom we search for as antagonists in a relationship dictated by written or implicit rules.

In the work described in this book and brought forward with the research on Human Body Interaction topics, we have tried to introduce two more specific anthropologies that define the mind-body relationship with a more contemporary view: *Homo saluber*, whereby humans lie in a system of search for wellness, and *Homo cogitans*, whereby self-consciousness in relation to physiological data becomes an interpretation and prediction tool.

Given this interpretation of the human spheres and, more specifically, the way they use and relate to their body, we may affirm that the body-instrument relationship has been mediated by physical and semantic interfaces, gradually conditioning their design in the direction of a formal abstraction of control elements and consequent virtualization (with the rise of digital systems). The design of such artifacts that mediate the human-tool relationship has sought growingly natural forms and ways to replicate interaction processes, gradually pushing (growingly invisible) machines towards the fusion between object and interface (Bonsiepe, 1995).

## Towards the body interface

Giving a contemporary definition of interface is not easy, and there is extensive literature on the topic including two very important texts along with the aforementioned ones: *Designing the user interface: strategies for effective human-computer-interaction* by Ben Shneiderman (1987), updated and renewed in different editions over the years, and *The Art of Human-Computer Interface Design* (1990), a comprehensive discussion by Brenda Laurel and S. Joy Mountford in which the two authors open the debate with the question: “What is an interface?”. In Computer Science, the term *interface* indicates all the situations in which human beings interact with computers, but in reality, this term embeds a deeper meaning.

Upon analyzing the different texts emerging halfway through the past century – in the second Postwar period – the now historical theories clearly highlighted how control instruments have become communication media between different biological, physical, and virtual entities. Such scientific studies show the effects of the cybernetics principles introduced by Norbert Wiener in 1948, highlighting a new design approach in which control, computation, and feedback are fundamental components placing communication processes at the center of the human-machine relationship.

The importance of Wiener's theoretical research also prevailingly affected design education: Tomás Maldonado introduced cybernetics at the Ulm School of Design in the late-'50s (Maldonado & Riccini, 2019), clearly stressing the importance of feedback in the communication process. Cognitive sciences have also built on the concept of feedback starting from Wiener's research and defining a series of principles articulated by Donald Norman (1988) on the design of digital artifacts. In this framework, the expressions of such guidelines for the development of user-friendly interfaces have given life to numerous theoretical contributions to the field of interaction design (Tognazzini, 1991; Moggridge, 2007; Preece et al., 2004; Kolko, 2011; Tognazzini, 2014). Such theories have consolidated in time and set the basis for the contemporary design of interactive artifacts we use daily through our devices.

In the contemporary discussion on interfaces, the perspectives developed by those who have attempted to define a research scope have originated a series of scientific formulations in the different disciplines and fields that researchers and designers worked in.

If we apply the concept of an interface to the body and not as an element inserted between a man and an object, the discussion is even more complex. In my previous book (2018), I tried to develop a taxonomy of prosthetics based on an arrangement described by Maldonado in *Critica della ragione informatica* (1997), introducing the topic of passive/interactive prostheses or wearable appendices. The subtle distinction between prostheses and wearable devices depends on the type of interface created with the body, with the interface's control becoming so natural it shifts human limits beyond their physical potential. Artistic experiments by Stelarc (Dunne, 2005, p. 31) and scientific works by Kevin Warwick (Barfield, 2016, p. 5) have abundantly confirmed the overcoming of such perceptive and motor limitations.

The topic of limits or boundaries becomes interesting when we see the human skin as the ideal biological container for the first element of interaction with external artifacts, going beyond its obsolete *holiness* and breaking ground for numerous technological experimentations.

The body interface becomes a point of connection and links the human with a network of objects. William Mitchell confirmed this by forewarning a design scenario in which humans are connected with their devices. He introduced a neologism – *Bodynet* – along with a personal interpretation of the controversial topic of cyborgs (Mitchell, 2010). We are experiencing a historic moment in which the human-artifact connection is no longer limited to the cognitive sphere but becomes a physical extension of the human. This will be the basis of future designs in which neurosciences and design will combine to make the relationship between such symbiotic products we are designing more natural (Biondi et al., 2009; Casoni & Celaschi, 2020).

The design of an interface is growingly more a field that straddles the cognitive and bodily spheres in which the elements are slowly moving from the currently dominant visual/tactile dimension to the physical/perceptive dimension, invading our bodies from head to toe. Although cognitive sciences had begun to enunciate interface design theories ever since the early-1900s, more specific studies have emerged in the past 30 years in which perception, visual attention, and memory aspects have been assessed in relation to artifacts for control and interaction with objects, machines, and systems.

In the early approaches, the interface design topic was associated with the topic of machine control or in the IT field as a way to exchange information between different systems, but as mentioned this is an oversimplification that does not consider all of the implications involving humans and their bodies. If we analyze the etymology of the term *interface*, we find that it includes the connotation of a *face-to-face* relationship between two entities. In this sense, which is focused on the physical relationship between the bodies of human and nonhuman entities, the interface migrates from a physical/tactile dimension to an intangible/ephemeral dimension based on formal and semantic aspects. In this nature in which it becomes a growingly thin and digital layer (Zannoni, 2014), corporeality has atrophied on small screens, relegating the interaction process to mainly visual aspects.

This control system through a screen is increasingly dominant and marginalizes the design research on forms of machine-body integration and the multisensory aspects that our perception mechanisms may provide to the interaction processes. It is safe to say that such tendency to reduce the interaction mainly to visual screens is not yet configured as a *path dependence*, and the interface design possibilities are still open enough that the role of the body is not destined to remain on the fringes of such design debate.

## Contemporary design scenarios of body interfaces

Given the experience gained in the past 20 years and based on literature, we may consider the graphic interface design context mature by now. The innovation processes that may be applied in this field are mostly incremental, and the implementation of possible disruptive innovations is unlikely. Desktop and mobile systems themselves have remained substantially unchanged in the past few years in terms of the conceptual models behind their design.

There is a currently open debate on the topic of responsive behavior of elements that leads to a reflection on minimum screen areas mostly designed for wearable devices and machines with control systems on their surfaces.

Such real-time control systems have evolved in parallel with the technology, and have turned from small and simple LCD screens to growingly accurate screens in terms of graphics and in the qualitative response to designer demands. The integration with the body has gained demand initially in the field of wearable devices for sports and, currently, everyday objects boasting functions dedicated to the generation of an individual's physiological data in the scope of personal well-being.

Whilst the control system has found a development on the body, achieving great versatility thanks to capacitive and tactile systems, the aspects related to feedback have not evolved, with the full range of haptic feedback relegated to vibration. On this topic, the field of natural stimuli (Dall'Osso, 2021, p. 43) is one of the most promising design scenarios for body-machine integration, although the rhythm and haptic feedback still remain insufficiently explored in literature and in design in general.

We have provided a wide range of experimentations on the topic in this book, and I shall only mention a few particularly interesting case studies. As far as the haptic feedback of touch in the absence of tangible elements, the work by Ultraleap[1] is a cutting-edge project whereby the human body perceives virtual shapes and objects through ultrasound (Romanus et al., 2019). On the other hand, the work done by Teslasuit[2] on feedback systems on the body is innovative and already marketed.

If, on one hand, the systems focused on communication methods through wearables and the body are rather promising, sensors and computer vision processes have, on the other hand, growingly evolved in the scope of tracking humans and their movements.

It comes as no surprise that nowadays we may use computer vision to track emotions very accurately. It offers the opportunity to design objects or systems allowing them to interface with man through a more comprehensive approach than their static geometry (Mengoni et al., 2021).

The broader topic of artificial intelligence is a primary research field in the evolution of human movement interaction and interpretation systems (Hayashi et al., 2021) that, depending on the tracking sensor type, allow the machine to hone its ability to interpret human movement in a new way. Little by little, machines are learning how to understand humans through their bodies and develop neural networks that embed the same more accurately.

While the machine is growingly able to observe us and understand us, it is tracking of the human body's vital signs that has become an impressive cultural phenomenon in the first twenty years of the 21st century. It has gained relevance in contemporary society and was studied in numerous projects related to the theme of the *quantified self* – a growingly popular personal awareness praxis from 2010 on.

This transformation in the way we understand our body, monitoring it with devices and analyzing the data it produces, has led us to gradually develop new data visualization tools to make the information collected by the sensors – currently affordable and accessible – visible.

Wearable devices can collect a wide range of vital parameters and such data, in most cases, show small variations that may only be understood when contextualized in a wider time interval. This initiated a design discussion on how to represent corporeal data and how to help individuals understand the same.

The representation of human anatomy and proportions began with Fidia and Hellenistic art and continued with the search for muscular perfection in the Renaissance, with the rediscovery of the geometrical proportions of the *Vitruvian Man* by Leonardo da Vinci and the research by Leon Battista Alberti, which appeared as descriptive and comprehensive representations of human nature. This technical evolution in the iconography of the human body found its maximum expression in anatomy publications that exposed the body's fragile envelope and represented each of its parts in detail. The flap-book *De humani corporis fabrica libri septem* by Andreas Vesalius (1543) was an interactive tool for anatomy students that – by means of the overlapping illustrations – allowed them to understand the position and relationship between organs.

According to Maldonado, it was at that historical time that the human eye violated the body's holiness and new scenarios for the awareness of the human body had birth (1994).

Such works had reached such a high level of description of the human body that they were unchallenged until photography was used for anatomopathological purposes and later the modern medical imaging techniques. I hereby report the beautiful initiative by Anders Ynnerman for the British Museum in 2014, where the scientist promoted and made accessible the vast majority of the Egyptian mummy collection through CAT scans viewable by the museum visitors on multitouch screens (Ynnerman et al., 2016).

A true paradigm shift in the representation of humans in relation to their proportions in architectural spaces occurred when the first-ever ergonomic and functional products were designed in the mid-20th century, with the first *Modulor* anthropometric scales of proportion by Le Corbusier (1950) and the anthropometric charts in *Designing for People* by Henry Dreyfuss (1955).

The complexity of the human's contemporary visual representation and the multitude of related data becomes central from the moment they acquire a primary role in body-machine communication that – in a setting of interaction with data – becomes the only tool to represent the infinitesimal variations in our self.

Today, we experience a technological addiction to smartphones that – in just over a decade – have blown away every other possible interaction tool. Nonetheless, this is not a definitive scenario: contexts in which we can design new, wearable devices in contrast with the totalitarianism of mobile devices may open up. Such technologies have been studied by numerous researchers and designers for decades and are reaching a suitable technical and formal maturity to enter the everyday markets and lives of people.

With the risk of homogenizing interface systems, pushing towards a mobile-first use is not the appropriate way to build interaction processes. It is evident that standardization helps to guarantee the usability of artifacts, but does not make the experience of humans seeking a gradual evolution new or alive.

Today we already have several kinds of wearable and augmented reality devices that are slowly undergoing miniaturization and integration with the body that will make them acceptable and suitable for daily use.

Such designs shall permeate the entire spectrum of human senses by pairing with sight, hearing, and touch. Experimentation concerning the vibration and communication aspects has only just begun.

**Notes**

[1] Ultraleap Ltd., https://www.ultraleap.com.
[2] Teslasuit, VR Electronics Ltd., https://teslasuit.io.

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# HAPTIC TECHNOLOGIES FOR SENSORY EXPERIENCES AND SENSATIONS DESIGN. THE SENSE OF TOUCH IN RESEARCH: REPLICABILITY, APPLICATION AREAS, AND ENABLING TECHNOLOGIES

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## Introduction

As part of the development of an increasingly interconnected system related to the phenomenon of globalization, technological progress, productivity, and innovation are the main driving forces and often the only key to designing a prosperous future for the international society.

The experience of a global pandemic represented a major breaking point from past scenarios. The social, economic, and political consequences opened the door to new trends in technological development by emphasizing the opportunities of digitization, but also its risks and shortcomings.

Social distancing and isolation as preventive measures for infection control showed the fragility of the social system and the inadequacy of digital tools not yet widespread or capable of projecting the full reality perceived by our senses into a virtual context. The consequences of an international pandemic event have a profound, even medium- to long-term impact on the social and psycho-physical health of a community (Arslan et al., 2021; Cantelmi et al., 2021).

In this scenario, the replicability of perception through the sensory system in a virtual context becomes the subject of in-depth study in different areas of research.

The field of enabling technologies, especially concerning augmented and virtual reality, has mainly focused on stimulating the sense of sight and hearing, limiting the in-depth study of interaction through the sense of touch.

Despite this, European research in recent years has delved into the topic of haptic perception and enabling technologies capable of reproducing the sense of touch. Design experience in different fields has opened multiple possibilities for these technologies, but an ethical reflection in this field is essential to

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understand their impact and how relevant a multidisciplinary approach can be in the design of projects that include these technologies.

## The sense of touch in the research framework: the evolution of haptic technologies

The sense of touch is often underestimated, but its importance both physical and mental to the individual is well known in the literature (Van Erp Jan & Toet, 2015).[1] The study of tactile perception has a long history, has been thoroughly analyzed in different cultural contexts, and is recognized as a universal language. Unlike other senses, touch has not only a physical value but also a spiritual value in some contexts. In Eastern Indian and Chinese traditions, the sense of touch is reminiscent of natural elements such as wind and is also of fundamental importance in the medical field and diagnostics (Grunwald, 2008). We also find interesting considerations in the Western tradition. Greek philosophers delved into the issues of sensory perception and, therefore, the sense of touch. It is precisely within the *De Anima* that they emphasize the complexity of the sense of touch and how different perceptions of what is tangible do not allow a clear identification of its characteristics, which very much depend on the individual.[2]

The legacy on the subject left by Aristotle has remained rooted throughout history and has often been recalled in the sensory analyses of later centuries. Interesting are the references and considerations written by Denis Diderot in the essay *Lettre sur les aveugles à l'usage de ceux qui voient* on tactile perception as a fundamental element of knowledge of reality, but also of communication. The French philosopher highlights precisely how the sense of touch is a fundamental means of conveying any kind of knowledge for deaf and blind subjects[3]. Indeed, the sense of touch is a vehicle for multiple information, and as the French philosopher already pointed out in the mid-1700s, touch-based language is a fundamental communicative tool for all individuals with visual and hearing impairments. Although the subject of touch takes on a certain relevance from a scientific point of view, historically it is the sense of sight that would be emphasized and stimulated through technological means over the centuries to the present day. Diderot himself dedicated his writings to the sense of sight while also recalling Cartesian concepts of visual perception through touch. The sensory experience of touch does not emerge precisely because of its association with other categories of perception, such as visual perception. It is not until the nineteenth century that we find the first narratives in which the sense of sight is disassociated from the sense of touch, and the scientific community focuses on a hitherto sacrificed topic (Classen, 1998).

It is precisely this cultural heritage that has influenced scientific research for the development of enabling technologies. Stimulation of sight, a sense considered primary by Western tradition, has played a predominant role in technological advancement. Thus, hearing has also received significant attention; while the replicability of tactile, olfactory, and the related sense of taste have only recently become the subject of research and development in science.

Tactile perception has dynamics and characteristics that are complex to replicate artificially. According to a modern definition offered by MIT's Encyclopedia of Cognitive Science, the modality through which touch perception is expressed is based on both cutaneous receptors found beneath the skin surface and kinesthetic receptors, which can be found in muscles, tendons, and joints (Wilson & Keil, 1999). Haptic perception provides not only information on the characteristics of objects and surfaces with which an individual comes into contact, but also sensations such as temperature and vibration.

The wide range of technologies on the market or currently under development that enable interaction involving the sense of touch is termed *haptics*. This term precisely confirms the influence of Aristotelian culture in technological development. The term is derived from the Greek "haptikos" – meaning "relating to the sense of touch"[4] – and "haptesthai", a term used by Aristotle to refer to the sensation of tactile perception in both *De Anima* and *De Sensu et Sensibilibus* (Paterson, 2007).

Historically, the earliest developments in the field of haptic interaction can be traced back to the mid-1850s, particularly in the context of remotely controlled robotics thanks to the studies conducted by Raymond Goertz (1949).

These early technologies had the ambition of providing tools to be able to perform risky activities, such as handling radioactive material remotely and improve the safety of operators in a hazardous work environment, such as a nuclear power plant.

In subsequent years, the research conducted has expanded not only its scope of application, but also the range of sensations that the technologies being developed and marketed can convey. The applications of this category of technologies thus embrace not only the world of telerobotics, but a wide range of scenarios where haptic feedback – of the haptic or kinesthetic type – is able to enrich the user experience by providing information through a perception-based communication model. In this context, the application of haptic technologies in the context of virtual reality is particularly interesting for our considerations.

The latest trends in enabling technologies are moving toward defining scenarios that can faithfully reproduce real spaces, situations, and behaviors in virtual simulated environments. In this context, the perception of one's own body and external stimuli become a key element to be able to perform any daily task: think of the manipulation of any everyday object or the interaction with a tool such as a hammer or drill.

The human body is constantly stimulated by physical pressures and forces that characterize the reality around us. For this reason, the absence of a physical dimension in a virtual context will lead the individual to live the virtual experience differently: adding haptic perception in an interactive virtual scenario such as the metaverse can make all the difference. In fact, there were already studies in this field in the early 2000s aiming to investigate whether the use of haptic feedback could improve the performance of a dynamic task (Huang et al., 2004; Young et al., 2003) and how crucial contextual stimulation of the senses of sight and touch are in object recognition (Chikai et al., 2013).

From the international market perspective, there are some sectors – including the automotive sector – where haptic feedback is particularly important because it can replace the exploratory and tactile qualities experienced through user interaction with physical buttons, which for reasons of design and technological advancement are less and less present inside vehicles (Breitschaft et al., 2022). The presence of stimuli capable of eliciting the sense of touch can make the environment with which an individual interacts more natural and contribute to safer interaction, especially in contexts where a high mental workload is required.

The naturalness of interaction and perception of haptic stimuli thus seems to be a particularly important issue not only for the design of virtual environments, but also for many other fields that are facing or will face an ever-deepening digital transition that can offer opportunities while limiting the potential risks involved.

Research in haptics has developed several technologies (Vezzoli et al., 2022) that can cover a wide range of haptic sensations, which can satisfy different scenarios. The use of vibrations can help develop inexpensive solutions for rapid interactions and is a technology already widely in use today, as in electronic devices. In contrast, kinesthetic technologies are characterized by greater complexity and high cost but are particularly functional for continuous interaction. There are also technologies that can generate haptic feedback either through a touchpad or at a distance without interacting directly with the device.

Moreover, haptic feedback can also be perceived through mechanisms that are not haptic technologies in the strictest sense but simulate the sense of touch: in this case we are faced with solutions that are defined as pseudo-haptic (Ujitoko & Ban, 2021).

Whatever the technology capable of generating haptic interaction (wearable elements, gloves, etc.) that we will explore below, what can be aimed at with the implementation of haptic feedback includes: increased realism or effective immersiveness; transfer of skills through training activities even remotely or in a mixed context; safe user experience of potentially risky activities; and improved accessibility and usability for users in performing activities in virtual environments.

Scientific research is increasingly moving toward the integration of these technologies in various fields and contexts, especially for training, rehabilitation, and telerobotics activities. In addition, the experience of the pandemic and the widespread use of isolation measures to counter the spread of the SARSCoV2 have directed research to further investigate the impact and implementation of these technologies in the context of complex social relationships, as we will elaborate on below.[5]

The importance of haptic feedback is also perceived in terms of social and technological inclusiveness: access to technological tools and the digital world for certain categories of users is not always guaranteed due to both economic and social inequalities.[6] Today, designers are becoming increasingly interested in new solutions that can implement the sense of touch in innovative designs, and it is essential for research to always keep ethical and inclusiveness aspects in mind. The goal is to structure a methodology that can promote an inclusive and ethical interface design for the conversion of activities from the real to the virtual world.

This is because starting from the embodiment theory, we know that tactile perception can also influence personal attitude and certain individual choices, as also shown by an experiment conducted in 2018 regarding the influence of tactile perception of objects of harder or softer texture for criminal judgment and punishment recommendations (Schaefer et al., 2018).

In a development context that is increasingly inclined to provide solutions that can reproduce the sense of touch, it is particularly important to consider not only the wide range of technological solutions that have been developed and are being developed, but also the actual impact of these technologies in different sectors for technological advancement that respects the human's natural physical, social, and emotional dimensions.

## Legal, social and design aspects for extensive application of haptic technologies

The inclination to social coexistence is inherent in human nature. The body's relationship with itself and its environment is how humans experience life.

Indeed, the body is the constraint to which we are ineluctably *nailed* to act in the world: it represents the channel to the outside world, the instrument through which the mind comes into contact with reality.

Our experience is constructed and organized, therefore, through a form of existence that is given to us by the body (Lo Presti & Madonna, 2020) and the range of its own senses. As various scientific studies in the field of neurophysiology have shown, the body has a cognitive memory that affects our learning, and differentiated areas of the brain are responsible for diverse activities ranging from planning and execution of movements to initiation and adaptation of movement. The American psychologist J.J. Gibson defines the haptic system as the individual's "sensitivity to the world adjacent to the body" (1966) and emphasizes the close connection between haptic perception and body movements since the haptic system utilizes information coming from the kinesthetic and skin systems. The sense of touch can thus be seen as an active multisensory system, which can also be classified into multiple types of touch.[7]

It is, therefore, necessary not to limit the experience of touch to the hand since the whole body "feels" through touch, and the skin is the largest organ of our body, composed of two layers: one more external, the epidermis, and one more internal, the dermis, which contains a high number of mechanoreceptors, responsible for the translation of mechanical stimuli into neuronal stimuli.

As anticipated, the sense of touch acquires strategic importance in both real and virtual environments. The social isolation we have been subjected to due to the pandemic in the past two years has shown how sensing each other's bodies carries not only physical but emotional weight, bringing back its centrality in scientific studies and research in various fields. Its loss, on a physiological level, cannot be fully compensated for by vision and can cause severe limitations in the perception of limb positioning and hand dexterity.[8] For this reason, it is important to provide accurate haptic feedback in virtual environments or in general through haptic technology.

Achievements in recent years show a range of technological solutions: from the ability to grasp and move a reconstructed object in a virtual environment, to the creation of wearable sensors, even hidden within textiles, that can be applied in various areas and can provide detailed haptic feedback.

Some technologies have focused primarily on dexterity by designing exoskeletons, stationary devices, and *sensitive* gloves that can allow the user to interact with and feel the object in the virtual world. Research and development in this area in recent years have been directed toward making gloves that are not only more ergonomic and easier to wear but also through which one can feel shapes, textures, stiffness, impacts, and resistance in the virtual world.

In this way, it was possible to devise training solutions in virtual and augmented reality, combining gloves and visors, related to multiple sectors: automotive, sports, gaming, industry 4.0, tele-maintenance, health, and aerospace engineering, to name a few.

As we anticipated, the first and main area in which research[9] has focused is tele-maintenance with haptic feedback, in which a user interacts with a remote environment via HMI. In this context, the user remotely controls a robotic system equipped with sensors and actuators. The forces/couples of the interaction are captured when the teleoperator is in contact with remote objects and are reflected as haptic feedback to the operator (Steinbach, 2016). Numerous studies have shown that haptic feedback improves task performance and the feeling of being present.[10]

The long-term goal of this type of research is to make teleoperation completely transparent, which means that the user will no longer be able to distinguish whether a task is performed locally or remotely through HMI.

However, how comfortable can one be with using such technological instrumentation?

Imagining an operator constantly wearing visors and gloves to accomplish his or her work task could be not only emotionally alienating but physiologically wearing. For this reason, the design and interface must take into account not only the user's physical condition but also the emotional condition. The tools through which tele-maintenance-related activities with haptic feedback are carried out must indeed feel natural, intuitive, and regulated.

While it is true that from the point of view of occupational safety the use of teleoperation tools has the potential to decrease the risks of even fatal accidents or injuries, one also wonders about the potential risks of choosing to conduct activities through these tools.

Consider the case of telemedicine and telesurgery in relation to medical liability: there are already some cases of litigation especially related to the use of different techniques during surgery.[11] Extending the field of surgical operations through instruments using haptic technology, especially by dislocating operations from one nation to another, or even to different continents, would certainly raise issues related to differences or even incompatibilities in the regulatory environment and regarding guidelines. In addition, the use of remote instrumentation with internet access for remote operations undoubtedly raises concerns about the security of sensitive patient data and possible tampering with the system, or damage due to latency. Finally, the surgeon's performance will always be mediated by the machinery he or she uses in the operative phase: flawless human execution may not correspond to optimal results when also taking into consideration instrument sensitivity, malfunctions, and – for example – inaccurate haptic feedback (Bailo et al., 2022).

Legal concerns may be raised not only in the field of telemedicine. Going into detail about the application of haptic solutions capable of reproducing the sense of touch in an extended reality context (XR),[12] how will consent to data processing and especially consent between users be handled?[13]

The first physical harassment in the virtual environment within the metaverse and beyond has already been reported (Basu, 2021). The benefits that interaction can bring in emotional terms can easily turn into violence.

Therefore, it is essential to design interaction models that meet both functionality and usability criteria, always considering tools to protect against misuse and the development of recommendations to limit the risk of online malfeasance, especially considering legal aspects that may arise, such as the concept of legal personality associated with an avatar.

As anticipated, haptic technology has also opened new frontiers of social inclusion for people with disabilities, visual in the first place, as it enables the transmission of much useful information by fostering communicability between the blind and the real world in a mutual dialogue.

Several recent international research and development projects in Europe have sought, in this context, to address three main challenges: perception of the environment, communication and exchange of semantic content, learning, and joyful life experiences. SUITCEYES[14] is an example of research and development of an intelligent haptic interface for deaf-blind users in which intelligent fabrics and sensors are combined to process images, recognize faces and objects, and learn automatically. Particular attention was paid to solving the design of soft and flexible interfaces based on users' needs, and tested together with them, with frequent evaluation and optimization. The technology developed consists of both a tablet with a haptic cover and a kind of vest that receives input from the outside and transmits it to the deaf-blind person's back through a haptic pattern, thus supporting two-way communication between users with and without disabilities.

A similar solution, but with other nuances, has been applied to the context of body movement.

This is GuiDance (Camarillo-Abad et al., 2018), a wearable technology application designed to guide users in a leader-follower dance (LFD). Instead of directing attention or movement to reach a certain place, it focuses on directing dance steps. The main goal is to facilitate dancing using wearable technology as a mediator. The prototype consists of vibrotactile actuators controlled through a Unity-based interface. Two studies conducted through this design have shown that users have reacted positively by finding the proposal pleasant and interesting, and that it is possible to guide someone remotely to perform a dance through haptic feedback alone.

This design direction undoubtedly considers values that are particularly significant in the European context, such as non-discrimination in a real and virtual context, as well as the digital divide. Thus, the development of solutions that improve access for vulnerable individuals is encouraged, especially taking into consideration the affordability of devices.

From the focus on the detail of the hands to sensors extensively distributed on the body, the idea of total haptic immersion has also been reached. In fact, a further step forward has been taken by following this research direction, particularly in textiles: new clothing equipped with technology with an almost futuristic feel in which haptic feedback is embedded.

Haptic sensations are important elements of fashion retailing, but they are greatly diminished in the e-commerce user experience. Online, touch-related clothing information is only hinted at through audiovisual and textual clues. Trends in haptic technologies and applications indicate that computer-mediated haptic experiences could fill this sensory gap.

Research on these developments and their implications for fashion brands is, to our knowledge, still limited. To fill this gap, research is being conducted (Ornati, 2019) – through appropriate qualitative and quantitative methodologies – on the following topics: how haptic properties are conveyed online; the relevance of haptics to product returns; fashion managers' interest in haptic technologies; and the perception of haptics by a potential user group (Ornati, 2019).

The case of *Magic Lining* (Kuusk et al., 2018), based on these intentions, is significant. It is a project born out of the collaboration between an artist – Kristi Kuusk – and Human Machine Interaction, psychologists, and neuroscientists (MAGICSHOES). The team worked on a prototype that aims to offer possibilities to alter people's perceptions of their bodies through sensors inside tissues. In detail, the project focuses on e-textiles to generate sensory feedback embedded in the inner part of the garment, which generates tactile analogies, for example, self-perception of a body composed of water, rock, or even a cloud, thus directly affecting body perception.

In conclusion, not only has haptic technology evolved over the years from an engineering and prototyping perspective, but it is paying increasing attention to adaptive design to cater to the shapes and needs of the human body. Research directions even at the European level are moving towards funding projects that can enrich virtual environments or digital tools in general with haptic perception. The potential of using technologies that can reproduce the sense of touch is evident not only in the areas mentioned above but in many other contexts involving interaction. Research in this area is still very recent, and it is crucial for it to be guided – especially in a context such as Europe – by ethical and moral principles that put the sensory and emotional experience of the user at the center by mitigating the risks of the spread of tools and models that can alter the naturalness of the interaction and inclusivity from both social and economic perspectives. The opportunities and needs associated with a new vision of society, interpersonal relationships, and work activities have affected the way reality is perceived both on a physical and emotional level.

Despite this, rapid diffusion of these technologies can be observed with very diverse modes of interaction and sectors of reference. Hence, the need for preventive insights from legal and psychological perspectives emerges. Structuring guidelines is crucial in the search for design solutions that can mitigate the major risks and nurture the benefits that haptic technology can provide.

**Notes**

[1] Among others, particularly interesting is this overview which summarizes the role of touch in the social context as follows: “Social touch is of eminent importance in inter-human social communication and grounded in specific neurophysiological processing channels. Social touch can have effects at many levels including physiological (heart rate and hormone levels), psychological (trust in others), and sociological (pro-social behavior toward others).”

[2] In particular, Aristotle in *De Anima* assumes that unlike the other senses, which have their own sensible and an identifiable medium, the sense of touch possesses peculiar characteristics. Touch is not in fact attributable to a sensible proper, but to different tangible and opposite objects: hot and cold, or wet and dry. Finally, the sensitives proper to touch depend on individual qualities: thus, for example, if we perceive cold we must be less cold than the perceived object. Moreover, through the allegory of the spear piercing the shield, which in turn strikes the knight, he explains the complexity of medium identification relative to tactile perception.

[3] Specifically, on touch as an element of communication we read: “[…] Our senses bring us back to symbols more suited to our comprehension and the conformation of our organs. […] We have made them for our eyes in the alphabet, and for our ears in articulate sounds; but we have on for the sense of touch, although there is a way of speaking to this sense and of obtaining its responses. For lack of this language, there is no communication between us and those born deaf, blind and mute. […] Perhaps they would have ideas, if we were to communicate with them in a definite and uniform manner from their infancy; for instance, if we were to trace on their hands the same letters we trace on paper and associated always the same meaning with them.” (Diderot, 1972)

[4] “Cambridge Dictionary” definition, online access https://dictionary.cambridge.org/, May 2022.

[5] Also consider H2020-funded European projects such as “Touchless” (https://www.touchlessai.eu/about).

[6] Consider just individuals with physical disabilities and the potential to limit discriminatory processes through functional haptic tools and interfaces for digital inclusion (McDaniel, Panchanathan 2019) as argued in the next chapter.

[7] Loomis and Lederman (1986) reworked Gibson’s thought to obtain a classification of the sensory system according to the inputs used. According to this classification, there are five different modalities of touch: tactile (cutaneous) perception; passive kinesthetic perception (kinesthetic responses without voluntary movement); passive haptic perception (kinesthetic and cutaneous responses without voluntary movement); active kinesthetic perception; active haptic perception. Only in the last two cases does the observer have motor control over the haptic exploration process.

[8] https://web.archive.org/web/20140124073640/http://www.roblesdelatorre.com/gabriel/GR-IEEE-MM-2006.pdf

[9] See the EU project PROHAPTICS. https://cordis.europa.eu/project/id/258941/reporting/it.

[10] *Ibidem*.

[11] The “Da Vinci” system, used globally for microsurgery operations, has indeed been the subject of controversy, especially in relation to the type of liability in the American legal system (Pradarelli et al., 2017).

[12] In this context we make the term Extended Reality (XR) an umbrella term that encompasses Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR).
[13] This issue emerges more frequently taking into consideration the access to new haptic technologies and virtual reality also to a wider audience of users with different domains, including that related to sexuality (Ley & Rambukkana, 2021).
[14] For further details, see the project's official website: https://suitceyes.eu/.

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FUTURE DESIGN
HUMAN BODY
INTERACTION
INTERNATIONAL SYM

# THE INTERNATIONAL SYMPOSIUM OF FUTURE DESIGN FOR HUMAN BODY INTERACTION

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## Where we are and where we started

The idea on which the International Symposium of Future Design for Human Body Interaction[1] is based – and so is this book, whose main aim is to describe the project – was born in 2020, during a historical period that the current circumstances nowadays authorize to define as pre-Covid time. Nonetheless, the pandemic situation itself can be considered as the most explicit demonstration of how the intrinsic bond between humans and their body, while too often neglected, needs to be re-conducted at the center of a discourse that aims to discuss the individual in its complexity. The Symposium was born to build a network of professional researchers who deeply investigate the state of the art and the possible future evolutions of human-machine interfaces. It was held in Bologna on June 22, 2021 (fig. 1).

The topic had already been raised and explored in Flaviano Celaschi's recent work on Human Body Design, where the professor stresses how the contemporary development of design economies progressively focuses on the individuals who, in a now globalized social context, increasingly seeks a product built and customized for their identity, including their body (Casoni & Celaschi, 2020; Celaschi, 2016). It is precisely for this reason that, nowadays, there cannot be a discourse on the design that is detached from of a user-centric perspective, capable of putting an in-depth study of the individuals and all their needs in the first place. However, in many cases, although properly conceived as a pivotal factor in design thinking, the user is actually configured as an abstract archetype, a centralizer of mostly behavioral functions that leave corporeality at the margins of the discussion. In the wake, therefore, of Celaschi's solicitations, and with the will to concentrate the research on the person as a whole, we decided to undertake a

On the left:
1. Michele Zannoni and Roberto Montanari during the Symposium keynote. Photo by Key Scampa.

path that had the aim of placing the human body exactly at the center of the design process.

The result of this operation is the project of the Symposium, that is a network of researchers, designers, and companies united in the name of the final objective of building an observatory[2] for the activation of research processes capable of investigating the concrete implications of the newfound centrality of the human body. Moving from a design perspective, the impacts that such specific attention on the human body could have in the design of physical and virtual interaction processes have been particularly privileged subjects of this observation (Zannoni et al., 2021a).

## The growing network of the Symposium

44 individuals from 7 different countries belonging to the academic and professional world responded to our call to take part in the project. They proposed about 70 case studies relevant to the Symposium. Further work carried out by our ADU research team has therefore integrated their reports by collecting a database that now counts about 300 projects and involves 460 people and 260 companies.

Three main areas of interest have emerged in this multitude and variety of subject and themes, which we defined as follows:

- *Homo faber*, an area mainly related to the tools that humans can build and use to achieve their goals;
- *Homo saluber*, an area mainly focused on the health of the human body as an organism;
- *Homo cogitans*, an area mainly related to the properly human characteristic of thought and prediction.

As can be seen from the definitions assigned to each of the three areas, which try to return a clustering of the activities of the Symposium by the different areas of afference, what remains at the center of our discourse is precisely the human being, in the various possible declinations of his way of relating to and interacting with the world (Zannoni et al., 2021b).

## The methodology of the Symposium

The Advanced Design Unit of the Department of Architecture at the University of Bologna has consolidated the Future Design framework as a methodological basis to develop, through a network of international observers, a process of research and anticipation in the field of design science studies. This approach to scientific research first appeared in 2017 and was refined in subsequent years. It aims to integrate knowledge, models, and networks from the micro to the macro and collect use cases and best practices: projects that start from the micro but speak to the macro.

The aforementioned definitions represent the final result of a process of research and analysis that has constituted the methodology at the basis of the Symposium (Celaschi et al., 2021, p. 16). Particularly, the project has been articulated in five different phases, namely:

- Phase 1: the basic research;
- Phase 2: the constitution of a network of expert observers;
- Phase 3: conduction of a census, cataloging, mapping, and interpretation of the significant cases in this context;
- Phase 4: the construction of a shared repository;
- Phase 5: the organization and presentation of the Symposium event;
- Phase 6: the construction of the permanent observatory.

The basis of our research is therefore constituted by real-world use cases, which have provided the possibility, on one hand, to raise attention on issues and themes that are in progress in the contemporary design field and in the market; and, on the other hand, to start from a solid basis for our observation, linked since its origins to a process driven and shaped by real data. It is precisely for this reason that the observers of our Symposium play a central role, constituting a direct approach to the field collection of the data gathered and organized within the shared repository. The organization of the Symposium event has undoubtedly played a key role in the project, by creating a moment of sharing and dialogue between all the participants. Finally, the results achieved allow and invite further evolution of the whole project, which, by transforming the miscellaneous group of observers into a network of continuous connections, allows the creation of a permanent observatory in direct contact with the trends and turning points of design and the contemporary market.

The following paragraphs will therefore account for the methodology applied and the results achieved by the project up to the organization of the Symposium.

*Basic research and construction of a network of observers*

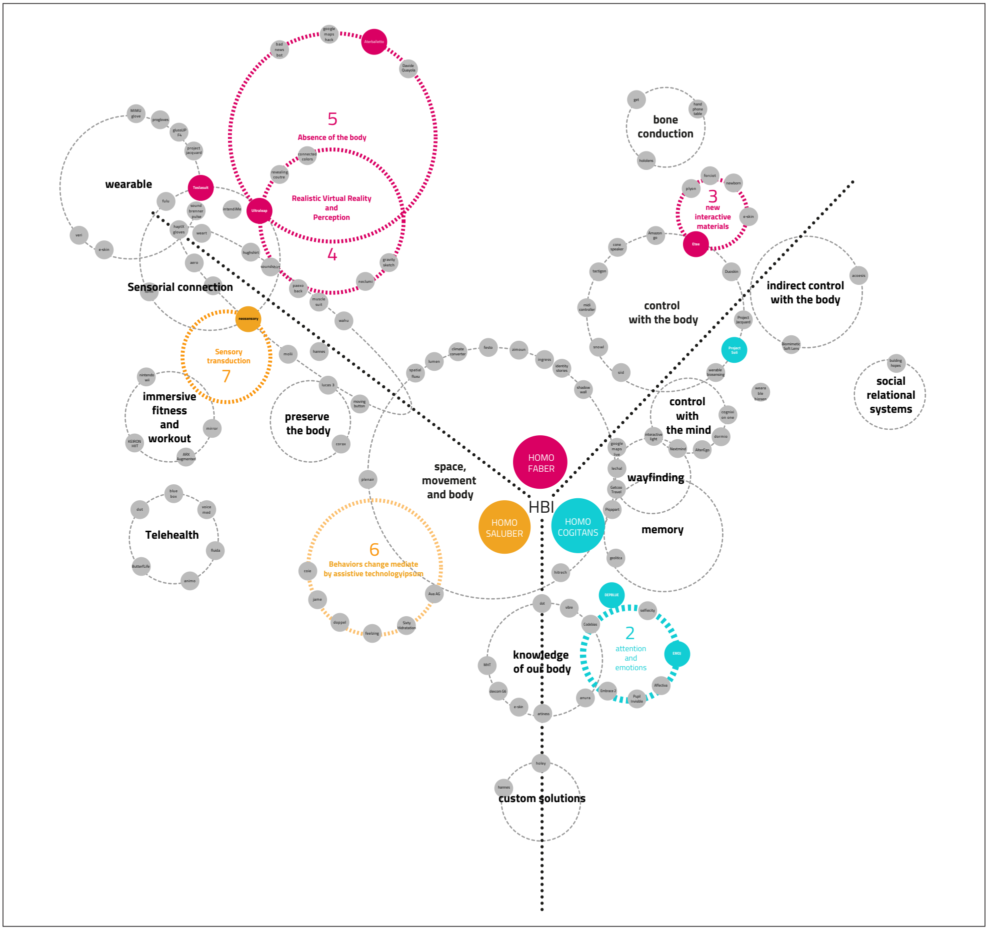
Conceiving the case studies found and analyzed during *Phase 1* of our methodological process as a constellation of themes articulated around the three main axes of our areas of interest, it is possible to create a diagram as shown in figure 2.

By analyzing the configuration that has thus formed, it is also possible to find some specific trends in each area. In particular, if in the left area, at the intersection between *Homo saluber* and *Homo faber,* it is possible to map case studies and products already available on the market. In the right area, centered around *Homo cogitans*, there are case studies still in a mainly prototypical and experimental research phase, which nevertheless prefigure a possible and hoped-for growth of new products and services.

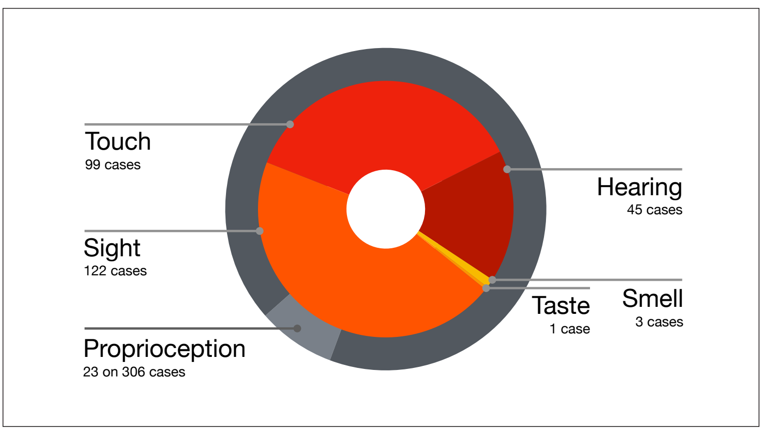
*Cataloguing the case studies*

In research based on scenarios focused on the user's corporeality, a cataloging tool for the analyzed case studies is naturally based on the sensory and perceptive aspects of the body itself. The five senses, in fact, constitute the five communication channels through which the interaction between the individual, the machine, and the world takes place. The various case studies mapped in the research have developed an approach to interaction that varies from time to time based on the chosen communication channel, that is on the sense (or senses) that have been mostly considered in the design and implementation of the interaction between the individual and the machine (fig. 3). By shifting the attention from the single case to the whole system, a perspective emerges that, through a photograph of the contemporary situation, allows us to catch a glimpse of certain trends that, though sometimes confirming what has already been ascertained in the past, sometimes shed light on new aspects and detectors.

The first assumption that can be made refers to the confirmation of the centrality of sight and the visual channel in the




2. Maps of the case studies and the field of application on the design themes.




3. Analysis of the senses involved and technologies enabling interaction.

interaction of the individual with the world, as most of the projects of the Symposium rely on this sensory dimension to connote the interaction process. However, promising explorations can be seen that focus on the use of other channels and sensory dimensions. As we will see, contemporary research on the adequate exploitation of the active haptic channel, which is a type of interaction that starts from touch and its sensory possibilities, has particular relevance. The aspects relating to vocal interaction and acoustic exploration, on the other hand, remain in the background, although their importance proves to be very relevant, especially in multitasking contexts. Finally, research on an interaction that involves or supports the olfactory and taste channels remains rather unfathomable ground. In this sense, one might wonder if the importance that these senses have assumed during the pandemic situation, due to the impact of the COVID-19 virus, could bring more attention to a field that is, for now, on the fringes of research.

*Mapping the themes that emerged*

Starting from the cataloging activity executed in the previous phase, in order to activate anticipation processes to understand the complexity of the contemporary situation in the design field and market, we have highlighted seven research themes corresponding to the speeches given by the guests of our event reported in the paragraph *The Symposium event*:

- The first is related to the relationship between the machine and the body and how artificial intelligence is used to improve the processes of interaction of digital systems with humans. (Refer to *Theme 1. AI to help machines understand human movements*);
- The second is related to the same concept but in the complex sphere of emotion recognition. (Refer to *Theme 2. Emotion tracking*);
- The third and fourth themes are linked to interaction with physical and virtual artifacts. New tools and materials can open up a new comprehensive interaction between the physical artifact and the digital dimension. (Refer to *Theme 3. New capacitive touch materials* and *Theme 4. Virtualization needs feedback*);

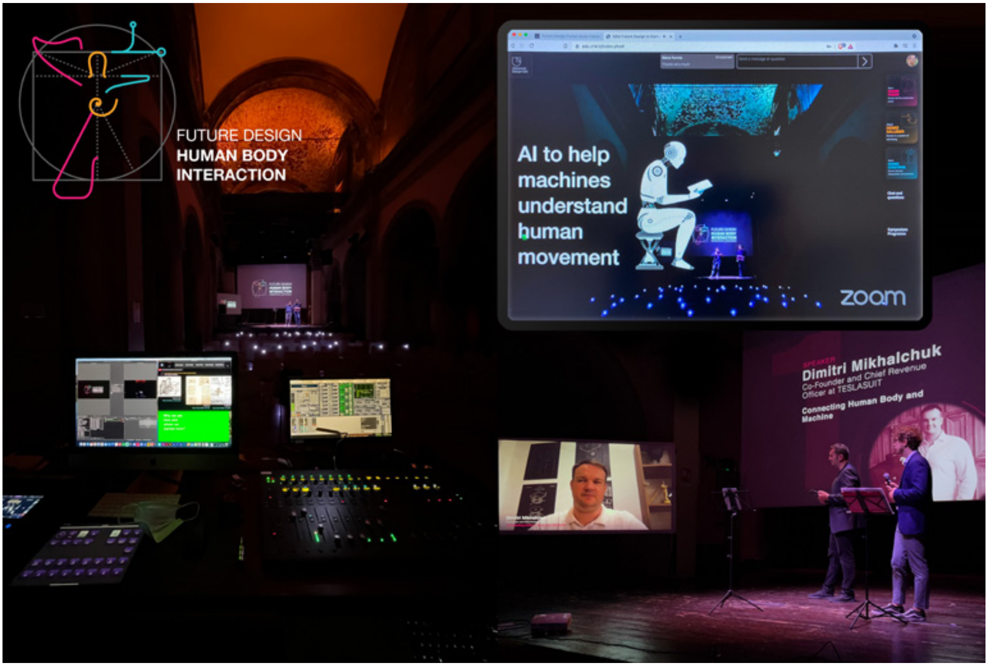
- The fifth theme is related to the absence of the body in social and learning relations, a topic that has seen exponential growth due to the COVID-19 limitations. (Refer to *Theme 5. The absence of the body*);
- The sixth field of research is mainly linked to the well-being area and the behavioral change processes triggered by assistive technology. (Refer to *Theme 6. Behavioral changes mediated by assistive technology*);
- The last theme is focused on the so-called *sensory transduction*, where the lack of one sense is shifted via technology to the other ones: a topic that is now moving from the prototype level to a productive dimension. (Refer to *Theme 7. Sensory transduction. A new perception of reality*).

In summary, these seven fields of research tell us about a complex scenario where the experiments that were prototypes at the beginning of this century are now becoming concrete B2B and B2C products.

## The Symposium event

The Symposium was an opportunity to confront in a digital and multidirectional way certain questions concerning the evolutions of the human-machine relationship. The event was held in a virtual mode in the San Leonardo theater in Bologna and it was organized by the main implementers of the project to create a moment of comparison and sharing between the various observers involved. The main goal was to gather scholars and active witnesses who are conducting experiments all around the world, to exchange insights. During the event, all the data involved in the projects and case studies collected during the research were available to view as a database integrated into the streaming platform (fig. 4). This was a preview of the observatory that would be opened to the public in the following months. To reduce the distance between the online attendees and the people in the theater, there was a lighting installation on the empty theater stall that indicated the online presence of the participants.

Based on the seven themes identified in the research, it has thus been possible to organize seven presentations in the morning




4. The San Leonardo theater in Bologna and the streaming platform. Photo by Key Scampa.

part of the Symposium concerning the main phenomena affecting the world of contemporary design in relation to a specific interest in the human body, conducted by experts and protagonists of these same changes.

*Theme 1. AI to help machines understand human movements*

The historical period in which this Symposium takes place is not irrelevant to the themes that have been brought to light. We are, in fact, in a moment of transition between two different models of human-machine interaction, which therefore needs to remodel traditional paradigms in an innovative and original perspective. In the current scenario in which we are moving from a model where it was the individual who controlled the machine through an interaction based on direct commands to a model where it is the machine itself to learn from people and their behaviors, it becomes necessary to acquire a new mindset able to overcome the traditional idea of the interface to create a new, more effective, and innovative model. The latter is naturally supported by artificial intelligence (AI), which is expected to be able to think, interact, and behave in ways that support humans by providing personalized, adaptive, responsive, and proactive services in a variety of settings (Pollini & Giusti, 2021).

In this perspective, an example of the implementation of AI-based technology for the understanding of human behavior has been provided at the Symposium by Leonardo Giusti, head of design at Google Atap[3] (fig. 5), the Google Device and services research and development lab. "As humans, we have this sort of implicit understanding of other humans' behavior and this feeling of being understood by other people without saying a word. But it never happens with technology. So, what if we could experience a similar feeling when we interact with a technological product? This is, in the end, the problem that we're trying to solve through the Soli project", he has explained to the public. Soli, a miniature radar sensor created by Google Atap, is a technological device able to understand human motion at different scales, from finger motion to full body motion. Thanks to radar and advanced machine learning algorithms (Hayashi et al., 2021), Soli allows the interpretation of small and large gestures as well as body language expressions, spatial relations, and even more complex activity patterns like social context, giving life to a new interaction language based on the continuous understanding of nonverbal communication cues. "If


5. Leonardo Giusti, head of design at Google Atap. The Symposium speech: https://youtu.be/h9u2eBGFKyk.

you think about that, this is very similar to the way we interact with each other", continues Giusti, stressing a fact that also constitutes one of the cardinal assignments of our project: the accent on human-machine interaction must be shifted towards humans and their natural way of behaving and communicating through verbal and non-verbal languages. The setup of neural networks, capable of interpreting human movement in an increasingly precise manner, is gradually becoming a stable reality that can be implemented in design processes. With some products already available on the market, a mature scenario is now opening, in which the designers and developers are becoming able to teach the machine to interpret human gestures and exploit that knowledge to realize deeply human-centered products.

*Theme 2. Tracking emotions*

Emotions constitute a spectrum of investigation for the recognition of the status of users whose importance has largely grown in recent years. Furthermore, they are beginning to be conceived no longer as separate factors but as concurrent and interdependent in the regulation of human behavior in its complexity. For example, the scientific literature in neuroscience leads us to consider the emotional state or its arousal as connected to phenomena such as cognitive load, attention distribution, or operational choices.

After the pioneering perspectives indicated in a famous book entitled *Affective Computer* (Picard, 1997), emotion recognition technologies have grown considerably in terms of flexibility and


6. Maura Mengoni, associate professor at the Polytechnic University of Mark and president of Emoj. The Symposium speech: https://youtu.be/yK7_2qEC6s0.

availability, to the point of being deeply rooted in the interface design process. In other words, it is now possible to state that interfaces no longer adapt only to the user's cognitive state or psychological-behavioral profile, but also to their emotional state.

As part of the Symposium, we wanted to give space – in addition to a wide range of technologies – to an Italian technological project dedicated to the theme of emotional recognition: Emoj.[4] Presented by Maura Mengoni, associate professor at the Polytechnic University of Marche and president of Emoj (fig. 6), the project gives life to software enabling the recognition of human emotion. It is based on a coding system including deep convolutional neural networks, enabling the recognition of age, gender, the six primary common emotions, violence, engagement, gaze, direction, and other indicators from pictures and videos captured by every type of camera. "We, as designers or researchers, have to measure objectively and quantitatively the reaction that people have when interacting with other products. Hence, we must know who the customers are, what makes them different from the others, how they feel, and what they want" stated Mengoni during her intervention at the Symposium. Thus, Emoj contributes to providing this kind of measurement by defining a holistic approach and an implemented technological framework oriented to the analysis of human system interaction at every touchpoint and to the adaptation of the user experience based on user state. Applicable in a large variety of fields, from museums to automotive, it highlights the importance and the innovative power of this kind of measurement based on

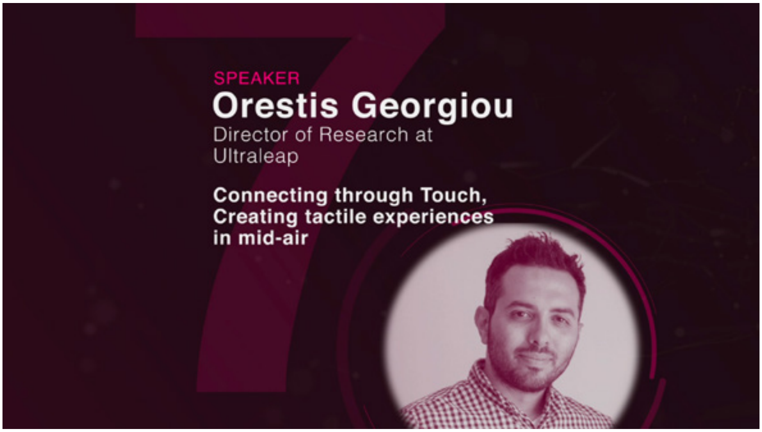

7. Jakub Kamecki, partnerships & alliances at TGO. The Symposium speech: https://youtu.be/S9gGvtJvMP8.

emotions to realize a sensitive, responsive, and personalized environment (Mengoni et al., 2021).

*Theme 3. New capacitive materials*
The last twenty years of interface development have been characterized by continuous research on screens for our devices to obtain increasingly defined and precise tools to trace the touch of our hands on their surface. However, the rigid and planar configuration of the screens is and keeps being a limitation in the interaction with human tactile capabilities. Some attempts to overcome this limitation have been produced, such as the OLED technologies, which have introduced the flexible screen, but the morphological limit of the shape has remained a crisis point, and the designers have had to integrate part of no-screen surfaces with capacitive sensors. The digital transition to a real tactile experience is still an unsolved goal.

Precisely for this reason, some recent projects, including the case study presented in this Symposium by the company TG0 (Tangi0 Ltd), are working on a new frontier of tactile interaction, moving toward the design and implementation of new interactive systems to connect human and machine through a profound link between the body and artifacts (Kong, 2020).

The main objective of TG0, as presented in the Symposium by Jakub Kamecki (fig. 7), is to "bring back the sense of touch as a way to interact with machines, through the creation of memorable controls". The intimate and private aspect of interaction is recreated by TG0 through the realization of 3D shapes and patterns that, with




8. Orestis Georgiou, director of research at Ultraleap. The Symposium speech: https://youtu.be/E2tPFFYBdeM.

the ability to detect every touch, gesture, pressure, movement, and deformation through a smart polymer approach, can offer the user an exciting way to interact with technology. The idea behind the project is that such kind of interfaces inviting the user to play with them can reduce the time and fatigue of the interaction while providing a more pleasant and fulfilling experience for the customer.

*Theme 4. Virtualization needs feedback*

As previously mentioned, touch is a sense that plays a tactical role for an interface designer. In fact, it does not have the same semantic foundation as the visual channel – that is, it does not allow exchanges of fine and detailed information. However, it is a strategic element to enable effective multimodal interactions, especially under multi-task conditions. Touch, if used carefully within an adequate interface, reveals all its tactical potential in constituting an almost immediate feedback element for the user, who can continue to devote all his visual or acoustic attention to something else. The active action of the tactile channel – namely, its ability to actively transmit a signal – is called haptics. The challenge of making the haptic channel an active, reconfigurable, and new language of interaction is at the center of two innovative projects that have chosen to present their research at the Symposium: Ultraleap[5] and Teslasuit.[6]

The first was proposed at the Symposium by Orestis Georgiou, director of research at Ultraleap (fig. 8). “While in immersive reality the visuals and the audio that we see are incredibly compelling, we’re completely missing feedback for our vital sense, a sense


9. Dimitri Mikhalchuk, Co-Founder and Chief Revenue, Officer at TESLASUIT. The Symposium speech: https://youtu.be/n1-XhgMGyE8.

of touch. […] Touch is both discriminative and functional, but it's also social and effective. It's a key aspect of how we connect and how we experience the physical and digital world. And more than that, we've got to move away from these handheld controllers if we are ever going to have a feedback mechanism for touch that is widely adopted for virtual and augmented reality", stated Georgiou. Focusing his research on the implementation of virtual tactile feedback and stressing the need of providing interaction even without specific devices – which sometimes are a limitation rather than a support – he has shown how haptic technology, by using sound waves to project tactile sensations and vibrations through the air and directly onto the user's hands and fingertips, represents a great resource for immersivity and accessibility in the virtual reality (Romanus et al., 2019).

The second project focuses on a discrepancy that is emerging in the interaction processes between two different scenarios of Human-machine relationships. "We are currently moving from the age of hands and touch, in which we operated buttons and knobs, to an age of mind and body, in which we use our body as a user interface. Human-machine interfaces are [becoming] gateways to ever more natural forms of communication between humans and machines. Hence, we find ourselves on the journey […] towards full immersion, a world in which our reality is overlaid, mixed, and even extended with the digital sphere." So states Dimitri Mikhalchuk (fig. 9), co-founder and chief revenue officer at Teslasuit. The compelling need and the challenge for the contemporary development of technological devices is thus the necessity to realize simple, easy-to-use, plug & play product interfaces that are familiar to the users and let them express themselves in the most natural way possible. Teslasuit, as a real technological exoskeleton able to collect and interpret biometric data obtained from the natural action of the human body, as well as its implementations in projects concerning real use cases, are perfect examples of how the new interfaces are propagated as more and more adaptive, almost symbiotic with the human body. The latter is thus enabled to spontaneously express itself in its naturalness, free from the forcing of traditional machine-oriented interactions.

*Theme 5. The absence of the body*

While in the previous themes, concerning virtualization, the aim was to materialize the feedback to support the illusion of interaction, in this theme the opposite problem is raised, which is how to deal with an interaction in which the body is, in fact, absent. This new condition of *being without a body* is not only a probable requisite of a future that is increasingly moving towards virtuality but has also been forcefully brought to light in the real world from the COVID-19 pandemic. In the emergency period, indeed, everyone has been called to confront the absence of the body in interaction – with others and with things – as a form of new normality. The restrictions on movements and gatherings have in fact led to the shift of interactive experiences to the frame of a video: from the three-dimensionality of the physical space to the two-dimensionality of the screen. If, on one hand, it is a condition to which we are now accustomed and which may seem acceptable to many of us, a critical reflection emerges, on the other hand, on the limitation of the perceptive process of the totality of the body. In this new mode of interaction, which excludes the physical coexistence of the two interacting subjects in the same place, the most invisible, yet fundamental, part of the communication, devoid of fundamental parts of body language, is missing. The very scope, intrinsic to the very nature of the interaction – the transmission of an emotional and empathetic message – is thus erased from the digital tools we use to connect.

The absence of the body as an interacting subject greatly limits the transfer of emotions between humans, impacting, among


10. Fabio Ferretti, project manager at Alterballetto. The Symposium speech: https://youtu.be/l6RQ2jteGm0.

others, even an area in which this aspect plays a fundamental role: that of performing arts. Feeling art through digital mediation is a critical issue of our times. Just imagine the different sensations experienced in a real or virtual visit to a museum or between a streamed or live performance of an artist's concert. However, in a reality in which the absence of bodies is destined to form – if not a new normality, at least a possible option – it becomes necessary to experiment with the interaction within and through new forms of conveyance of the emotional process. One of the most notable experiments in this area was conducted by one of the participants in the Symposium, the Aterballetto foundation.[7] Indeed, their recent project investigates new languages and interaction methods to not lose the emotions of dance in a totally virtual environment. It is based on a double change of perspective: on one hand, an approach to new and innovative media and technologies for this type of art form; on the other, a new concept of the user experience from its very foundations. In fact, using the Oculus, which allows a virtual and immersive user experience, the viewer is brought directly to the stage, at close range with the dancers who can interact with him through a direct and deep channel. Thanks to choreographies specifically designed for this type of virtual fruition, and recorded through the cinematic viewer, it was, therefore, possible to find a new communication channel to realize, in the words of the speaker Fabio Ferretti, "a virtual dance for real people, to create a new experience that is no longer a live show but could also exist after the live show" (fig. 10).

*Theme 6. Behavioral change mediated by assistive technology*

Our behavior is naturally presented in the face of change with a suspicious attitude and a leathery spirit. In other words, changing behavior is complex and often futile. As Kurt Lewin (1947) points out, change pathways must find facilitation, that is *channels* of transition from one behavior to another or from one habit to another. In other words, behavior may change more easily if guided through a facilitated and rapid path, from which it is difficult to exit and not complex to enter, which leads us – forcing us, so to speak – towards change. Interfaces and many media and devices are designed to promote virtuous behavioral changes. However, not all people act by seeking out the channels we referred to earlier. Instead, some of them reinterpret the channeling and enabling factors that act through effective physical and perceptive solicitations.

One of the fields in which the innovation of human skills and behaviors can undergo the most changes is that of aviation, whose new areas of investigation were illustrated at the Symposium by Simone Pozzi, CEO of Deep Blue[8] (fig. 11). In apparent contradiction with the idea of innovation advocated by contemporary media, but following what was previously stated on resistance to changes in human behavior, Pozzi wants to remind us how "the world is a slowly-changing domain" in which innovation represents a "long-term process". Also, in a field perceived as technological and advanced as aviation, the key question is whether innovative changes in the current systems, through the introduction of new technologies now available or developable in the market, are truly advantageous for humans and their performances. On one hand, it is true, for example, that automation supports humans in both regular and critical operations, allocating functions between humans and machines. However, automation can be very problematic because it makes the system harder to control in the processing phase. The goal here is thus to overcome the basic status in which automation works well in normal conditions to exploit all its potential in order to maximize situational awareness, support decision-making, and enhance performance execution in critical and non-anticipated situations. At the same time, it is necessary to find and develop the technologies necessary to monitor different human


11. Simone Pozzi, CEO of Deep Blue. The Symposium speech: https://youtu.be/k7-ONHbSqQs.

statuses and answer properly to them and the situation. From this perspective, two helpful means are undoubtedly the AI and human monitoring systems, which are fields of interest and research for the company.

In any case, speaking of these issues, one cannot avoid a question that, even in the case of Pozzi, remains open and which, in our opinion, constitutes a fundamental starting point for future reflection of the Symposium and its research, namely: how much, how, and to what degree of possibility will it be possible to change the behaviors and skills to be possessed by men in correspondence with the changes applied to the machine system?

*Theme 7. Sensory transduction. A new perception of reality*

When speaking of technology and the human body, different devices have proven to help us in transformative processes and are now consolidated factors in the replacement of missing or deficient parts of our bodies. As addressed several times, prosthetics have acquired maturity and an increasingly faithful rendering of the human body and the elements of nature. Functional fruition and replacement are giving way to paths centered on processes of *sensory transduction* in which the lack of one sense is transferred to another through the use of technology that commutates the signals in different representations, from Neil Harbisson's first experiments on the cyborg at the beginning of this century – in which he tried to compensate the lack of part of the electromagnetic spectrum


12. Scott D. Novich, co-founder, and chief technology officer at Neosensory. The Symposium speech: https://youtu.be/pOk4yg_xo_8.

vision – to the research that Neosensory[9] has presented at the Symposium (Eagleman et al., 2019). The scenario reported by Scott D. Novich (fig. 12), co-founder and chief technology officer of the company, shows a potential that leads us to imagine a design mutation of perceptive possibilities toward an increasingly hybrid sensorial communication.

"Sensory augmentation is the idea that there's some information out there that can be perceived kind of natively in the way we think of sound, vision, or touch. And we can do this non-invasively by encoding this information to reach some target set of sensory receptors in our body. The challenge is to do [this] in a smart enough way such that we guarantee that as much of the information that we care about makes it to the brain", Novich explained. The challenge and the aim of sensory augmentation are thus to bridge the gap between the information present in the world and the possibility to receive it by our senses.

The devices developed by Neosensory are, in fact, able to take information from the environment and find the proper mathematical representation to realize the appropriate encoding to let the information reach the target sensory receptors in the human body (Novich & Eagleman, 2015). Thanks to a re-interpretation of the sensory information available in reality based on the receptive possibilities of the individual, Neosensory is configured as a good example of how technology and innovation can be the right means to not only amplify but even allow the interaction of Human with the surrounding world.

## The discussion panels

The Symposium was organized in two parts. The morning was dedicated to the guests' presentations and the afternoon to discussion panels on three specific topics that participants could sign up for. The first panel with the title: New Ergonomics, Challenges, Applications, and New Perspectives was moderated by Roberto Montanari and Andreas Sicklinger with the guests Mirko Daneluzzo (DIDI Dubai Institute of Design and Innovation), Andrew Morris (Loughborough University), and Fabio Mattioli (The University of Melbourne). The second panel, called Designing for wellbeing: data and behavior changes, was moderated by Giorgio Casoni and Giorgio Dall'Osso with the guests Mario Fedriga (Technogym), Carlo Tacconi (mHealth Technologies). The last panel, titled Human-Machine Interaction design: interfaces, services, and processes was moderated by Alessandro Pollini and Michele Zannoni and presented the researches of Margherita Peruzzini (University of Modena and Reggio Emilia), Francesco Tesauri, and Leandro Guidotti (RE:Lab), Andrea Peraboni (SDI Automazione), Angela di Massa (BSD design), and Francesco Grippo (EMAG SU).

## Conclusion and lessons learned

The presentations heard so far, as well as the research, cataloging, and sharing activities that have been carried out during the project, demonstrate how we are at the beginning of a process of understanding the new relationship between design and the body, which has been approached according to the product and market logic, but which is now changing towards a dimension of design for the well-being of the individual as well as the community.

The seven design directions that we have highlighted, and which we had set out to investigate, represent only a few of the many possible paths between the three defined macro-areas of the *Homo faber*, *saluber*, and *cogitans*. The evidence of the cases analyzed in the Symposium shows us that it is now necessary to open a structured multidisciplinary debate on these themes, which to this day have only been analyzed as emerging technologies and their potential to construct artifacts and services, but could now open a new age of transformative artifacts for humans and their bodies to achieve a new level of well-being for people in respect of the physiological and cultural differences.

## Notes

[1] International Symposium Future Design Human Body Interaction, Bologna, June 22, 2021, https://adu.unibo.it/humanbodyinteraction. The symposium proponents were: Flaviano Celaschi, Elena Formia, Roberto Montanari, Andreas Sicklinger, and Michele Zannoni with the scientific collaboration of Giorgio Dall'Osso and Marco Pezzi. The workgroup consisted of: Luca Barbieri, Andrea Cattabriga, Alberto Calleo, Arianna Fantesini, Lucrezia Rivieccio, and Ludovica Rosato. A special thanks to Annalisa Mombelli and Elisa Silva for their important contribution to the systematic collection of the material in this project.
[2] Human Body Interaction Observatory, https://adu.unibo.it/hbi/.
[3] Google Atap, https://atap.google.com.
[4] Emoj S.r.l, https://www.emojlab.com.
[5] Ultraleap Ltd, https://www.ultraleap.com.
[6] Teslasuit, VR Electronics Ltd, https://teslasuit.io.
[7] Aterballetto Fondazione Nazionale della Danza, https://www.aterballetto.it.
[8] Deep Blue S.r.l, https://dblue.it.
[9] Neosensory Inc., https://neosensory.com.

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# THE HUMAN BODY INTERACTION OPEN DATABASE

*Michele Zannoni*, Giorgio Dall'Osso*, Ludovica Rosato*, Luca Barbieri**

## A database as a multilevel dialogue tool

In the methodology adopted in the Human Body Interaction project of the Department of Architecture of the University of Bologna, a research tool designed within the Advanced Design Unit was used: the HBI open database. The reason for adopting the database was to improve collaborative processes in knowledge development.

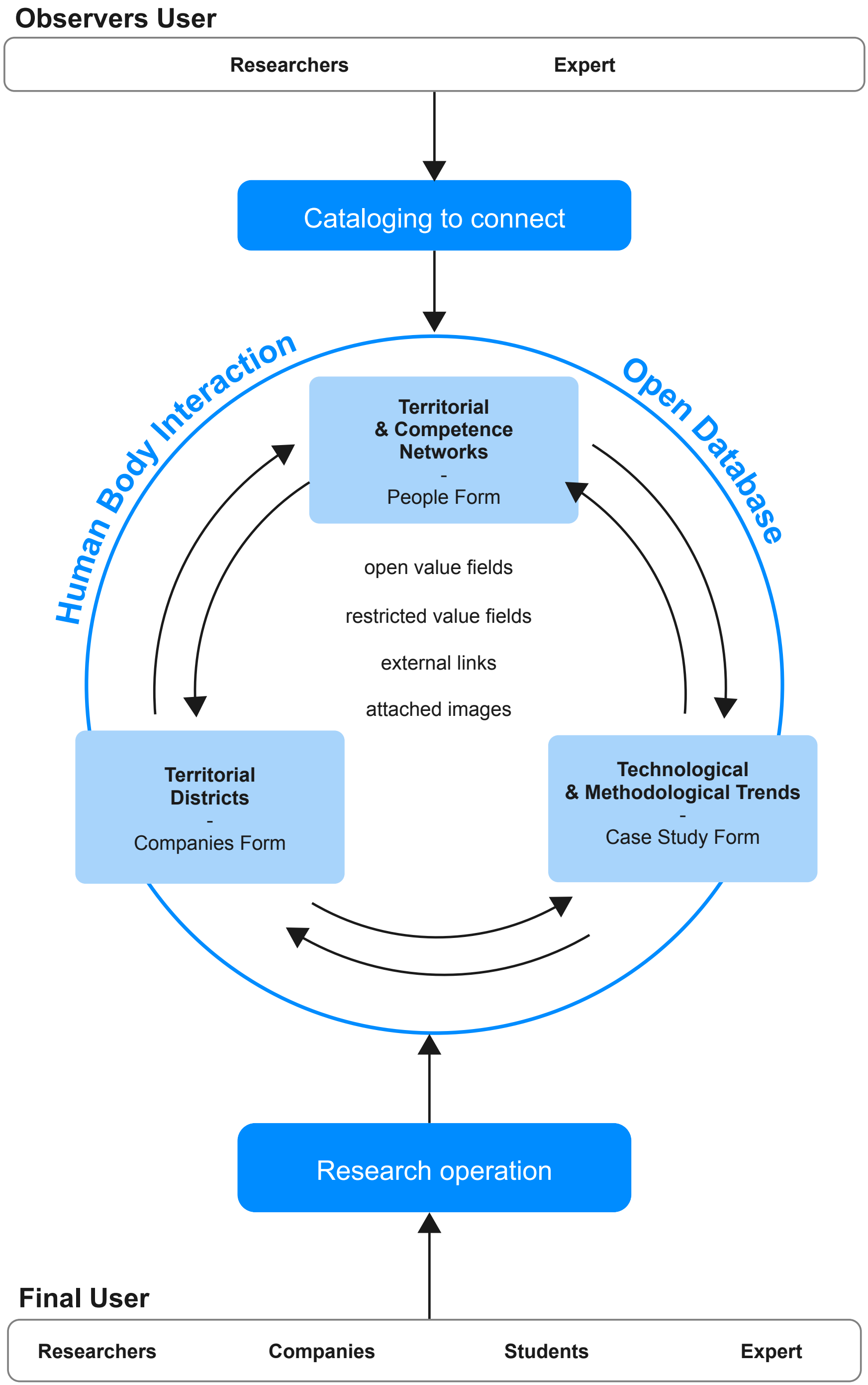
In the context of collaborative tools, numerous technical solutions allow a lot of information to be cataloged in a shared way. In many cases, these are closed commercial solutions that, while serving open-science processes, are difficult to modify and whose licenses are not suitable for future research developments.

The ADU research group platform for sharing and cataloging case studies is the tool at the heart of the Human Body Interaction Observatory project; its goal is to create relational cataloging of projects at the international level linked together through technological, scientific, and social relationships (fig. 1).

The common thread of the case studies is the search for innovation processes in the relationship between digital technologies and the physical, chemical, and relational properties of human bodies.

The platform is designed to centralize the cataloging process among different ongoing projects and with the possibility of developing outputs dedicated to research and the third mission. The HBI observatory system presents two interfaces: the first one is aimed at workgroup research and case study cataloging; the second one is dedicated to the public through free access in the scope of open science. The open-access service is presented as a web-based workspace divided into regular two-dimensional grids. Within each module, there is an image

** Dipartimento di Architettura, Alma Mater Studiorum - Università di Bologna, Italy*


Observers User
Researchers
Expert
Cataloging to connect
Human Body Interaction
Open Database
Territorial & Competence Networks - People Form
open value fields
restricted value fields
external links
attached images
Territorial Districts - Companies Form
Technological & Methodological Trends - Case Study Form
Research operation
Final User
Researchers
Companies
Students
Expert

and the name of the case study. Selecting one of the modules provides access to the descriptive tab of the case study characterized by textual information, images, tags, and links inside and outside of the platform.

The features of the interface serving the workgroup are focused on the function of entering new case studies. Researchers together with expert reporters – figures who joined the research over the course of the project – can fill out a descriptive form that relates multiple cataloging tables consisting of open and restricted value menus. The data entry process allows a link between researchers, designers, and companies; it also enables the storage of an apparatus of sources and information through links inside and outside the platform that ensure the completeness of case study communication.

Effective cataloging of the case study is achieved when relationships are built with all those involved in the project, from designers to all the figures within the companies and the university.

The goals behind this research and data exploration tool are to bring out the similarities and connections among the case studies clearly. In this way, common design references can be generated within the networks that exploit the platform for research.

In fact, this database is a working tool designed as a platform for dialogue among designers, companies, and researchers who wish to identify new lines of research and design through the correlation and interpretation of an archive of common case studies.

## Cataloging to connect

*Case study form*

A form is used to file case studies in which 4 types of information are requested (tab. 1):

- attached images;
- external links that allow further investigation of the case study;
- open value fields to be filled in with text;
- restricted value fields.

The table below shows the information, which is not mandatory, required in the scheduling process. Importantly, new tags can be created contextually with each entry. In this way, the unique description of projects is dynamic. The chosen tags clearly and quickly define the special features of the case study and allow it to be found among many.

Table 1. Case study form.

| | | | |
|---|---|---|---|
| **Attachments** | | | |
| Images | | | |
| **External links** | | | |
| Case study Link | Video Link | Reference/source Link | Scientific Paper |
| **Open value filling** | | | |
| Title | Description | Year | Awards |
| Funds | Note | | |
| **Restricted value filling with internal tags** | | | |
| Rate | Thematic fields | Technologies | Definition Level |
| Organization | Person | Designer | Collaborators |
| Countries | Client | Type of intervention | Material |
| Signaler | Commodity Sector | | |

For this reason, the work of tagging is of high relevance to the system's functioning. To avoid subjective categorizations, classifications were identified that could guide the research team in the early stages of mapping. Emphasis was placed on the subcategories of senses and digital technologies used.

*Business form and people form*

In addition to the cataloging of case studies, the platform also enables the cataloging of companies and people. This action highlights the relational and territorial networks of the case studies. Through territorial, typological, and relational affinities it is possible to identify territorial districts and intercept the emergence of networks around specific skills.

In both forms, it is possible to include information as in the case study form. Moreover, in the company form, it is possible to indicate the sector and related active people in the database.

In the people form, in addition to basic data, it is possible to indicate the role, personal website, biographies, links to interviews, territory of action (country and city), and years of professional and/or scientific activity. It is then possible to associate *LinkedIn* pages to activate possible project collaborations among database users.

*Research operation*

The database can be useful for researchers, practitioners, and students who need to perform research on topics related to the relationship between enabling technologies and the human body.

The first level of information is achieved by directly opening individual case studies on the showcase homepage of the database.

Deeper levels of research are achieved through the selection of tags. These are available in a cloud configuration within the menu divided into three sections: tags, technologies, and countries. Once one or more tags have been selected, case studies containing the selected tags remain available in the showcase.

Within tag clouds, moreover, tags turn on and off automatically. Specifically, all tags that are not related to the selected one turn off while the others remain selectable.

The relationship between tags shall have been stated within the case studies, which in this way become the node of the relational network.

Once you have identified a case study of interest, you can also identify other related case studies by selecting the tags of interest. More case studies with the same tag will appear in the pop-up window, and in this way, the researcher can increase the pool of collected case studies.

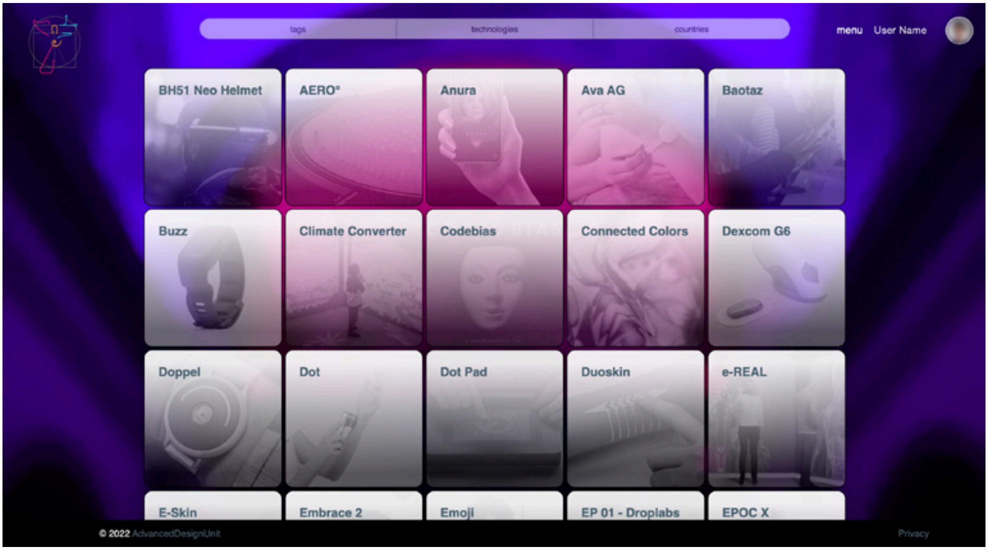
Once the researcher has identified a case study, the database allows the researcher to reach other similar case studies through the selection of tags of interest. More case studies with the same tag will appear in the pop-up window, and it will thus be possible for the researcher to increase the pool of collected case studies.

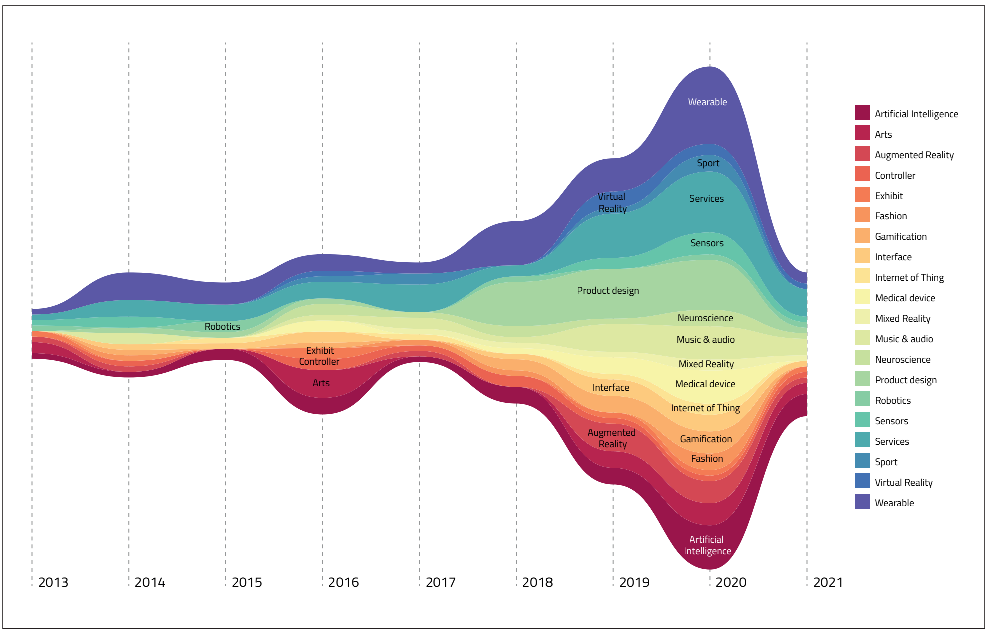
## Discussion

The case studies collected mainly refer to the 2019-2021 period but there are also examples of projects from the first decade of the 2000s (fig. 2). The collection represents cartography of the current state of interaction processes between humans and technology. In such fields, the analysis of the body parts and physiological processes involved is a key research element. For this reason, within the categorization process, emphasis was placed on the human senses activated in the case studies. Most of the case studies relate to technology through sight (123 projects), which is the first form of knowledge. Secondly, touch (94) and hearing (49) are catalyzers of attention. Numerous projects have proprioception (26), haptics, but also gestures as the primary means of activating interaction. Such projects make unusual use of sensors by collecting information often in the form of big data. The latter is one of the most mapped technologies in the database. In many case studies, big data (41) is used in projects for monitoring and tracking body-related data and is visualized through web applications, which is the most widely used tool. The database also shows that a widely experimented technology today is AI (81), followed by augmented reality (25).

Regarding innovation by sector, it is remarkable that most of the case studies identified are in the medical and wellness/well-being sphere. Products in this sector are mostly wearables but also digital services that communicate with users through digital interfaces. It is therefore common that case studies from design studios, companies, and university research integrate multiple design methodologies in the production of these multi-level objects. Product, interaction, and experience design are the design fields that are most involved in tackling the same macro-theme in very different ways.

As anticipated, the database and the relationships it brings to light can be useful to identify territorial districts. Most of the case studies collected come from Italy (121), the United States (62), and finally the United Kingdom (36).




1. The HBI observatory web site.

2. A case study analysis in the years 2013-2021.

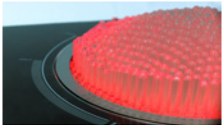
## Conclusion

During the first few months, the development of the platform underwent numerous advancements regarding the processes and data entry methods according to the needs of the research group. These advancements were particularly directed at two objectives: increasing efficiency by simplifying the filing process and improving the readability of the database. As for the first point, a horizontally scrolling interface was developed to keep the filing tools in view at all times. As far as the second point goes, an interface with pop-up tabs was launched, allowing the tabs to be opened while maintaining orientation within the workflow.

The database is now a shared working tool that allows a relational filing, which can be adapted to multiple research projects by adapting to the research context and the people collaborating in the project.

Future developments of the platform will be directed towards improving the collaborative and decision-making processes to improve the validation tools for cataloging and the use of information. A specific forthcoming objective will be to map the large number of categories. They are a fundamental value for the relational platform but represent a complexity to be managed in-use and which – in the continuation of the project – can be put at the service of the HBI observatory. As the database grows, the tags will also change and increase according to, for example, the obsolescence of technologies and future innovations. In addition to this, a possible future integration could include a collection of tags linked to parts of the human body.

**Acoesis**
(2019) https://adu.unibo.it/hbi/u/256
1 active and assisted living aal, hearing, music & audio, product

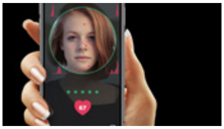


**AERO**
(2018) https://adu.unibo.it/hbi/u/309
2 big data, data physicalization, haptic pressure

**Aladdin**
(1999) https://adu.unibo.it/hbi/u/1430
3 ambient information display, force feedback, haptic, touch,

**AlterEgo**
(2019) https://adu.unibo.it/hbi/u/251
4 ai, hearing, neural interface, touch, wearable

**Animo**
(2020) https://adu.unibo.it/hbi/u/86
5 ar, gamification, health, physical rehabilitation, proprioception

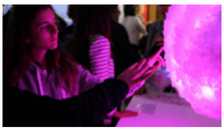


**Anura**
(2020) https://adu.unibo.it/hbi/u/402
6 ai, biometric sensor, computer vision, health,

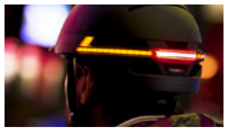
**Artiness**
(2018) https://adu.unibo.it/hbi/u/153
7 3d holographic, 3d rendering, mixed reality, sight, startup

**Ava AG**
(2018) https://adu.unibo.it/hbi/u/206
8 health, monitoring system, sight, sleep, touch

**BalanceBelt**
(2020) https://adu.unibo.it/hbi/u/1453
9 health, wearable



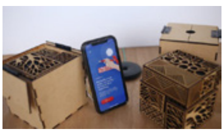
**Baotaz**
(2016) https://adu.unibo.it/hbi/u/406
10 ai, art, big data, data physicalization, semantic analysis



**BH51 Neo Helmet**
(2020) https://adu.unibo.it/hbi/u/1600
11 iot, orientation, product design, urban mobility, wearable

**Biologizing the Machine**
(2019) https://adu.unibo.it/hbi/u/1429
12 ai, art, multisensory, sight, smell

**Bionic Chair**
(2014) https://adu.unibo.it/hbi/u/1576
13 controller, force feedback, interaction, product design

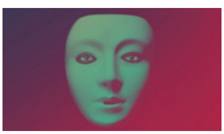


**Bukas**
(2021) https://adu.unibo.it/hbi/u/76
14 3d scanner, ar, laser, sight, touch

**ButterfLife**
(2020) https://adu.unibo.it/hbi/u/193
15 anamnesis, health, medical device, sight, touch

**Buzz**
(2013) https://adu.unibo.it/hbi/u/315
16 haptic, health, hearing, touch, wearable

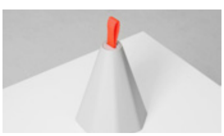
**Climate Converter**
(2019) https://adu.unibo.it/hbi/u/123
17 collective interaction, experience design, gamification, hearing



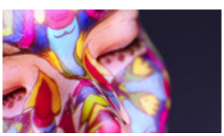
**Codebias**
(2020) https://adu.unibo.it/hbi/u/404
18 ai, facial recognition

**Cognixion one**
(2021) https://adu.unibo.it/hbi/u/196
19 ai, brain computer interface bci, hearing, mixed reality, neuroscience

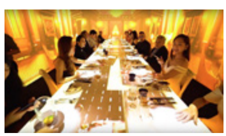
**Coie**
(2020) https://adu.unibo.it/hbi/u/236
20 experience design, hearing, product design, sight, touch



**Cone bluetooth speaker**
(2019) https://adu.unibo.it/hbi/u/89
21 gesture, hearing, interface, music & audio, natural language interface



**Connected Colors**
(2016) https://adu.unibo.it/hbi/u/353
22 art, projection mapping, visual arts



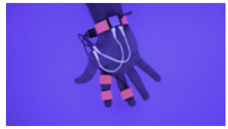
**Crave 4d**
(2020) https://adu.unibo.it/hbi/u/1580
23 multisensory, projection mapping, projection wall, sight, smell

**Dexcom G6**
(2019) https://adu.unibo.it/hbi/u/203
24 ai, diabetes, experience design, health, hearing

**Ditto Wearable**
(2012) *https://adu.unibo.it/hbi/u/311*
25 *notifications, wearable, wellbeing*

**Dodecaudion**
(2011) *https://adu.unibo.it/hbi/u/370*
26 *gesture, music & audio, service, spatial relation*

**Doppel**
(2015) *https://adu.unibo.it/hbi/u/307*
27 *haptic, natural language interface, rhythmic entrainment, touch*



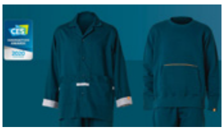
**Dormio**
(2018) *https://adu.unibo.it/hbi/u/173*
28 *biofeedback, neuroscience, product design, wearable, wellbeing*

**Dot**
(2020) *https://adu.unibo.it/hbi/u/144*
29 *ai, anamnesis, interface, medical device, sight*

**Dot Pad**
(2021) *https://adu.unibo.it/hbi/u/1599*
30 *accessibility, ai, blindness, braille, haptic*

**Duoskin**
(2016) *https://adu.unibo.it/hbi/u/258*
31 *controller, interface, spatial relation, touch,*

**e-REAL**
(2011) *https://adu.unibo.it/hbi/u/1452*
32 *ar, collective interaction, educational, mixed reality*

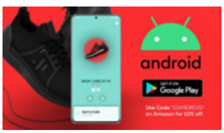


**E-Skin**
(2019) *https://adu.unibo.it/hbi/u/363*
33 *biometric sensor, health, medical device, motion analysis, service*

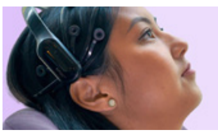
**Embrace 2**
(2016) *https://adu.unibo.it/hbi/u/154*
34 *ai, health, neuroscience, touch, wearable*

**Emoji**
(2017) *https://adu.unibo.it/hbi/u/389*
35 *ai, algorithms, emotion recognition, machine learning, service*

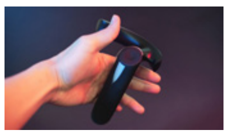
**Emotion Haptic Sleeve**
(2021) *https://adu.unibo.it/hbi/u/1455*
36 *blindness, emotion recognition, facial recognition, sight*




**EP 01 - Droplabs**
(2019) *https://adu.unibo.it/hbi/u/1417*
37 *ar, haptic vibrators, music & audio, virtual reality, wearable*

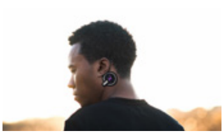


**EPOC X**
(2018) *https://adu.unibo.it/hbi/u/1561*
38 *controller, neural interface, neuroscience, product design*

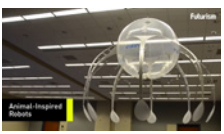


**Etee**
(2020) *https://adu.unibo.it/hbi/u/393*
39 *controller, haptic, interactive material, mixed reality, sensors*

**Exogun Wrap**
(2020) *https://adu.unibo.it/hbi/u/1427*
40 *health, sport, wellness*

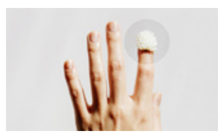


**Feelzing**
(2020) *https://adu.unibo.it/hbi/u/390*
41 *neuroscience, neurostimulation, sensors, wearable*

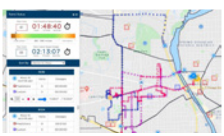



**Festo Animals**
(2010) *https://adu.unibo.it/hbi/u/351*
42 *bionics, natural movement, robotics, spatial relation*

**Forciot**
(2015) *https://adu.unibo.it/hbi/u/379*
43 *interactive material, interface, iot, product design, touch*



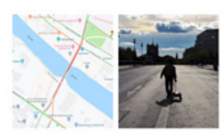
**Fulu**
(2019) *https://adu.unibo.it/hbi/u/176*
44 *ar, haptic, touch, wearable*



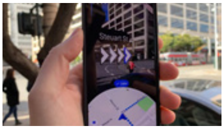
**Geolitica**
(2012) *https://adu.unibo.it/hbi/u/220*
45 *ai, big data, semantic analysis*

**Get**
(2015) *https://adu.unibo.it/hbi/u/212*
46 *digital wellbeing, haptic, hearing, service, sight*

**GlassUp F4**
(2017) *https://adu.unibo.it/hbi/u/270*
47 *ar, hearing, iot, mixed reality, service*



**Google Maps Hacks**
(2020) *https://adu.unibo.it/hbi/u/401*
48 *body absence, performing arts*



### Google maps live view
(2019) *https://adu.unibo.it/hbi/u/373*
49 *ar, proprioception, service, sight*

### Gravity sketch
(2021) *https://adu.unibo.it/hbi/u/334*
50 *controller, industry, service, virtual reality*

### Hannes - Prosthesis Hand
(2018) *https://adu.unibo.it/hbi/u/160*
51 *health, medical device, product design, prosthesis, robotics*

### Haptx Gloves DK2
(2019) *https://adu.unibo.it/hbi/u/382*
52 *force feedback, haptic, microfluidic haptic, motion capture, service*

### Hitrech Evo Kit
(2019) *https://adu.unibo.it/hbi/u/232*
53 *big data, optical sensor, prediction, proprioception, service*

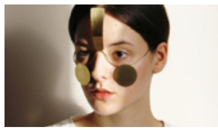
### Holey
(2016) *https://adu.unibo.it/hbi/u/225*
54 *3d modelling, 3d printing, 3d scanner, health, medical device*


### HUGSHIRT
(2004) *https://adu.unibo.it/hbi/u/253*
55 *collective interaction, fashion, haptic, multi-user, pressure sensor*

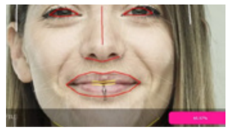
### Identity stories
(2021) *https://adu.unibo.it/hbi/u/75*
56 *exhibit, experience design, hearing, multisensory, music & audio*

### Illusion
(2019) *https://adu.unibo.it/hbi/u/1581*
57 *projection mapping, projection wall*

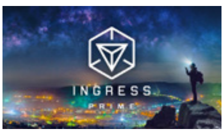
### In love with the world
(2021) *https://adu.unibo.it/hbi/u/1428*
58 *art, robotics, sight, taste,*



### Incognitio
(2019) *https://adu.unibo.it/hbi/u/408*
59 *facial recognition, product design*



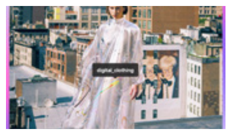
### Indice di Stendhal
(2021) *https://adu.unibo.it/hbi/u/244*
60 *ai, algorithms, art, emotion recognition, machine learning*




### Ingress
(2012) *https://adu.unibo.it/hbi/u/345*
61 *ar, game*

### Interactive Light
(2014) *https://adu.unibo.it/hbi/u/185*
62 *ar, gamification, interaction, interface, projector*

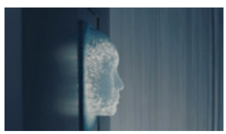
### Intomacy
(2018) *https://adu.unibo.it/hbi/u/157*
63 *collective interaction, haptic, interaction, multi-user*



### Iridescence
(2020) *https://adu.unibo.it/hbi/u/355*
64 *3d modelling, blockchain, digi-couture, fashion, nft*

### Jame
(2021) *https://adu.unibo.it/hbi/u/403*
65 *active and assisted living aal, ai, health, parkinson, wearable*

### Jaspr - Woodoo
(2016) *https://adu.unibo.it/hbi/u/378*
66 *automotive, display, interactive material, touch*

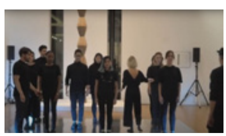


### Kagami
(2016) *https://adu.unibo.it/hbi/u/394*
67 *exhibit, projection mapping, video mapping*

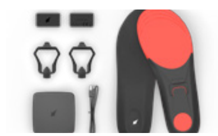
### Keiron HIIT
(2016) *https://adu.unibo.it/hbi/u/168*
68 *computer vision, proprioception, sight, touch, virtual reality*

### KINETIC Reflex
(2016) *https://adu.unibo.it/hbi/u/313*
69 *haptic, health, industry, motion analysis, proprioception*

### KitMe
(2015) *https://adu.unibo.it/hbi/u/291*
70 *deafness, haptic, health, hearing, startup*



### L'Odyssée du Toucher
(2017) *https://adu.unibo.it/hbi/u/322*
71 *music & audio, performing arts, touch electronic board*



### LECHAL sole
(2014) *https://adu.unibo.it/hbi/u/352*
72 *blindness, haptic, health, orientation, spatial relation*

**LEGO¬Æ Braille Bricks**

(2020) *https://adu.unibo.it/hbi/u/165*

73 *blindness, braille, educational, touch*

**Lift**

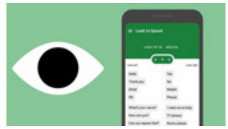
(2019) *https://adu.unibo.it/hbi/u/1416*

74 *health, movement disorder, product design*

**Liteboxer**

(2020) *https://adu.unibo.it/hbi/u/170*

75 *hearing, sport, touch, wellness*



**Look To Speak**

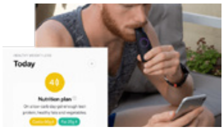
(2020) *https://adu.unibo.it/hbi/u/72*

76 *ai, hearing, mobile app, music & audio, neuroscience*

**Lucas 3**

(2016) *https://adu.unibo.it/hbi/u/348*

77 *cardiopulmonary resuscitation cpr, health, medical device*




**Lumen**

(2022) *https://adu.unibo.it/hbi/u/1596*

78 *health, healthcare nutrition, iot, mobile app*


**Lumen MR**

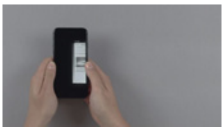
(2019) *https://adu.unibo.it/hbi/u/95*

79 *ar, exhibit, gamification, interface, mixed reality*

**M HKA Wall**

(2020) *https://adu.unibo.it/hbi/u/77*

80 *collective interaction, exhibit, communication and media,*



**Magic UX**

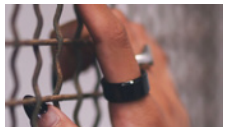
(2019) *https://adu.unibo.it/hbi/u/96*

81 *ar, gesture, interaction, mobile app, sight*

**Makr Shakr**

(2015) *https://adu.unibo.it/hbi/u/333*

82 *ai, experience design, food, robotics, service*



**Melo Ring**

(2019) *https://adu.unibo.it/hbi/u/197*

83 *gesture, interaction, music & audio, touch, wearable*

**Mictic**

(2018) *https://adu.unibo.it/hbi/u/376*

84 *gamification, gesture, hearing, motion capture, music & audio*


**Midi Controller Touchme**

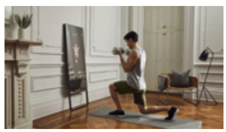
(2020) *https://adu.unibo.it/hbi/u/320*

85 *music & audio, performing arts*

**MIMU glove**

(2014) *https://adu.unibo.it/hbi/u/167*

86 *flex sensor, haptic, imu sensor, led, music & audio*



**Mirror**

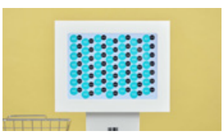
(2016) *https://adu.unibo.it/hbi/u/296*

87 *computer vision, motion capture, product design, sight*

**Mollii**

(2010) *https://adu.unibo.it/hbi/u/349*

88 *electrostimulation, health, medical device, neuroscience*



**Moving buttons**

(2021) *https://adu.unibo.it/hbi/u/328*

89 *interaction, interface, service, sight, touch*

**Mudita Pure**

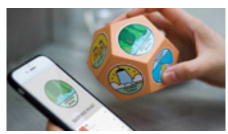
(2020) *https://adu.unibo.it/hbi/u/94*

90 *hearing, product design, sight, touch*

**Muscle Suit**

(2015) *https://adu.unibo.it/hbi/u/343*

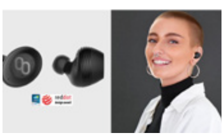
91 *exoskeleton, industry, robotics, wearable, wellbeing*



**Musy**

(2018) *https://adu.unibo.it/hbi/u/125*

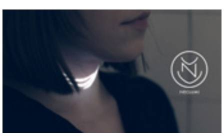
92 *experience design, gamification, gesture, hearing, interaction*



**MYMANU**

(2014) *https://adu.unibo.it/hbi/u/317*

93 *ai, hearing, wearable*



**Neclumi**

(2014) *https://adu.unibo.it/hbi/u/369*

94 *fashion, interaction, projection mapping, service, sight*

**Neuroshirt**

(2020) *https://adu.unibo.it/hbi/u/1454*

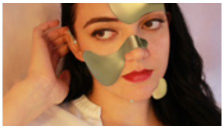
95 *feedback, haptic, health, medical device, wearable*

**NEWBORN**

(2017) *https://adu.unibo.it/hbi/u/73*

96 *clothes, fashion, sostenibility, touch*

**NextMind**
(2019) *https://adu.unibo.it/hbi/u/384*
97 *controller, neural interface, neuroscience, product design*



**Orwell**
(2020) *https://adu.unibo.it/hbi/u/409*
98 *cybersecurity, emotion recognition, facial recognition, product design,*

**Paexo Back**
(2020) *https://adu.unibo.it/hbi/u/350*
99 *exoskeleton, health, industry, wearable, wellbeing*

**Paper Phone**
(2019) *https://adu.unibo.it/hbi/u/65*
100 *product design, ui user interface, wellbeing*


**PASSO**
(2021) *https://adu.unibo.it/hbi/u/335*
101 *health, hearing, natural language interface, parkinson*

**Petting Zoo**
(2013) *https://adu.unibo.it/hbi/u/388*
102 *ai, art, exhibit, natural language interface, natural movement*

**Play Impossible Gameball**
(2020) *https://adu.unibo.it/hbi/u/179*
103 *game, product design, service, sight, sport*

**Pleinair**
(2019) *https://adu.unibo.it/hbi/u/327*
104 *interaction, sensors, service, spatial relation, wellbeing*

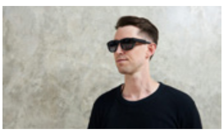
**Plyon**
(2021) *https://adu.unibo.it/hbi/u/381*
105 *automotive, interactive material, sensors, service*

**Practico**
(2017) *https://adu.unibo.it/hbi/u/1597*
106 *interiors and furniture,*

**Progloves**
(2020) *https://adu.unibo.it/hbi/u/342*
107 *industry, laser scanners, wearable*

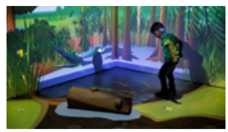

**Project Jacquard**
(2016) *https://adu.unibo.it/hbi/u/330*
108 *gesture, interaction, service, ui user interface, wearable*

**Project Soli**
(2016) *https://adu.unibo.it/hbi/u/329*
109 *ai, gesture, interaction, ui user interface*

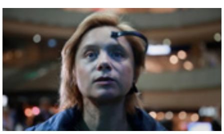


**Pupil Invisible**
(2020) *https://adu.unibo.it/hbi/u/341*
110 *iot, product design, service, sight, wearable*

**Revealing Couture**
(2020) *https://adu.unibo.it/hbi/u/354*
111 *art, memory - remembrance, video*

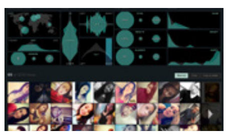


**River of Grass**
(2017) *https://adu.unibo.it/hbi/u/1527*
112 *biodiversity, collective interaction, educational, multi-user, projection*

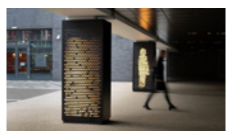


**S7 Imagination Machine**
(2016) *https://adu.unibo.it/hbi/u/372*
113 *controller, experience design, gamification, neural interface*

**Scaeva InSitu**
(2020) *https://adu.unibo.it/hbi/u/377*
114 *hearing, memory - remembrance, music & audio, wearable*

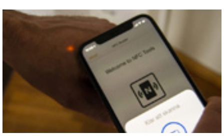


**Selfiecity**
(2015) *https://adu.unibo.it/hbi/u/397*
115 *ai, big data, instagram*



**Shadow Wall**
(2019) *https://adu.unibo.it/hbi/u/122*
116 *collective interaction, experience design, interaction, sight*

**Shampora**
(2018) *https://adu.unibo.it/hbi/u/280*
117 *ai, cosmetics and personal care, fashion, service, wellbeing*



**Siid**
(2019) *https://adu.unibo.it/hbi/u/121*
118 *biohacking, internet of thing, medical device, touch*

**Silmu**
(2020) *https://adu.unibo.it/hbi/u/156*
119 *experience design, problem solving, product design, spatial relation*

**Simulated Reality**
(2010) *https://adu.unibo.it/hbi/u/383*
120 *imaging 2d/3d, interaction, service, stereoscopic image, ui*


**Sixty Hidratation Monitor**

(2018) *https://adu.unibo.it/hbi/u/162*

121 *biometric sensor, health, product design, sight, touch*

**SleepMate**

(2020) *https://adu.unibo.it/hbi/u/102*

122 *ai, hearing, interaction, product design, sight*

**Smart Beaming**

(2021) *https://adu.unibo.it/hbi/u/1425*

123 *directional audio, music & audio, spatial relation*

**Soundbrenner Pulse**

(2015) *https://adu.unibo.it/hbi/u/314*

124 *haptic, music & audio, natural language interface*


**SOUNDSHIRT**

(2020) *https://adu.unibo.it/hbi/u/252*

125 *ar, bluetooth, fashion, haptic, hearing*

**spatial flux**

(2018) *https://adu.unibo.it/hbi/u/346*

126 *haptic, health, wearable, wellbeing,*

**Surfacide**

(2020) *https://adu.unibo.it/hbi/u/208*

127 *disinfection, product design, service, sight, wellbeing*

**Tactigon**

(2018) *https://adu.unibo.it/hbi/u/174*

128 *ai, arduino, controller, product design, proprioception*

**Teslasuit**

(2019) *https://adu.unibo.it/hbi/u/392*

129 *gamification, haptic, interaction, monitoring system, product design*


**Tg0**

(2015) *https://adu.unibo.it/hbi/u/380*

130 *capacitive sensing, interactive material*

**The Handphone Table**

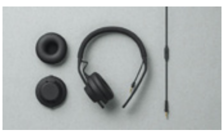
(1978) *https://adu.unibo.it/hbi/u/344*

131 *art, music & audio, touch*

**Time Capsule**

(1997) *https://adu.unibo.it/hbi/u/1598*

132 *memory - remembrance, performing arts*



**TMA-2**

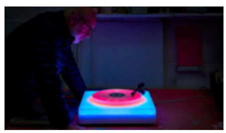
(2019) *https://adu.unibo.it/hbi/u/106*

133 *hearing, music & audio, product design, sostenibility*

**Transform Visitors**

(2016) *https://adu.unibo.it/hbi/u/74*

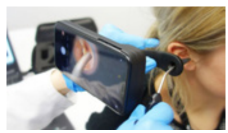
134 *exhibit, experience design, interface, sight, touch*



**Turntable**

(2021) *https://adu.unibo.it/hbi/u/1585*

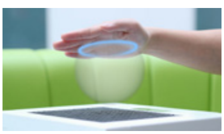
135 *colour, music & audio, sight*



**Tympa Health**

(2020) *https://adu.unibo.it/hbi/u/259*

136 *hearing, interface, product design, service, sight*



**Ultraleap**

(2013) *https://adu.unibo.it/hbi/u/298*

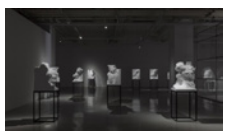
137 *ar, haptic, interactive experience, mid-air haptic, touch*

| Country | Total Instagram users | Female Instagram users | Instagram users as a share of population |
|---|---|---|---|
| European Union | 138.3m | 54% | 31% |
| Germany | 23.0m | 52% | 28% |
| Italy | 22.0m | 50% | 36% |
| France | 20.0m | 55% | 30% |
| Spain | 18.0m | 54% | 38% |

**Undress or fail**

(2020) *https://adu.unibo.it/hbi/u/400*

138 *paper*



**Unfinished Sculptures**

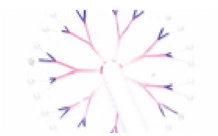
(2016) *https://adu.unibo.it/hbi/u/395*

139 *3d modelling, art*

**Upmood**

(2018) *https://adu.unibo.it/hbi/u/87*

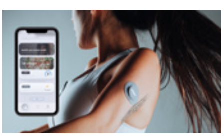
140 *ai, heart rate variability hrv, wearable, wellbeing,*



**Venous materials**

(2020) *https://adu.unibo.it/hbi/u/374*

141 *haptic, interaction, interface, pressure sensor, sight*



**Veri**

(2020) *https://adu.unibo.it/hbi/u/391*

142 *biometric sensor, food, health, healthcare nutrition, mobile app*


**Verso**

(2017) *https://adu.unibo.it/hbi/u/213*

143 *controller, gesture, interaction, music & audio, proprioception*

**Vibre**

(2017) *https://adu.unibo.it/hbi/u/148*

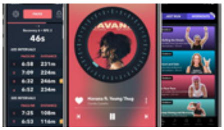
144 *biometrica, monitoring system, neural interface, neuroscience*

### Vickey
(2015) *https://adu.unibo.it/hbi/u/289*
145 *cybersecurity, internet of thing, product design, startup*

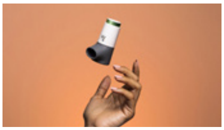
### voice med
(2020) *https://adu.unibo.it/hbi/u/302*
146 *ai, biofeedback, deep learning, hearing, medical device*

### WAHU
(2020) *https://adu.unibo.it/hbi/u/318*
147 *ai, sensors, spatial relation, wearable*

### Weather system
(2020) *https://adu.unibo.it/hbi/u/235*
148 *arduino, big data, data physicalization, iot, prediction*



### Weav Run
(2017) *https://adu.unibo.it/hbi/u/1426*
149 *music & audio, sport, wellbeing*



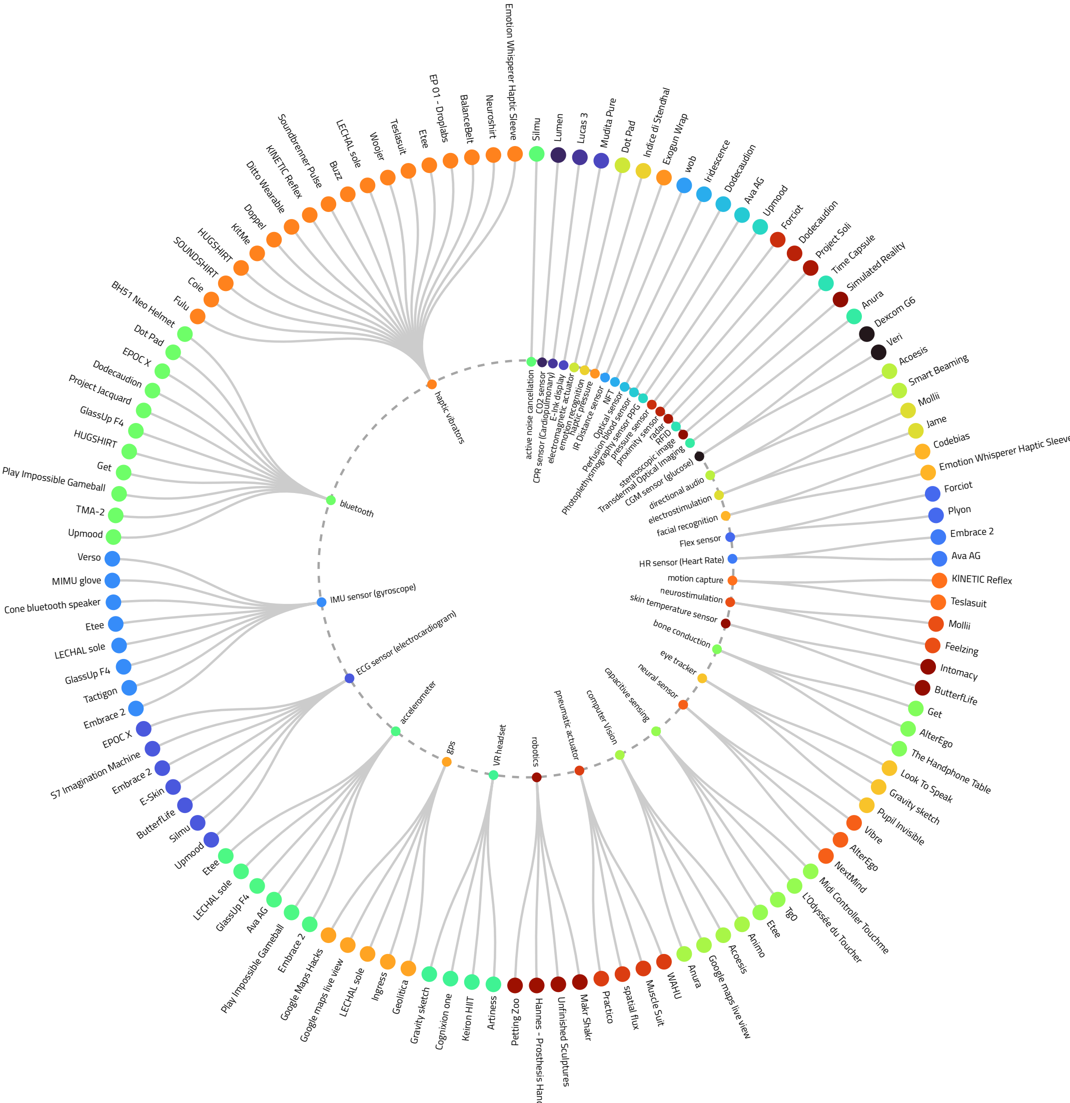
### Wellbeings mist inhaler
(2020) *https://adu.unibo.it/hbi/u/207*
150 *health, medical device, product design, service, smell*

### Wise
(2019) *https://adu.unibo.it/hbi/u/356*
151 *hearing, medical device, service, sight, touch*

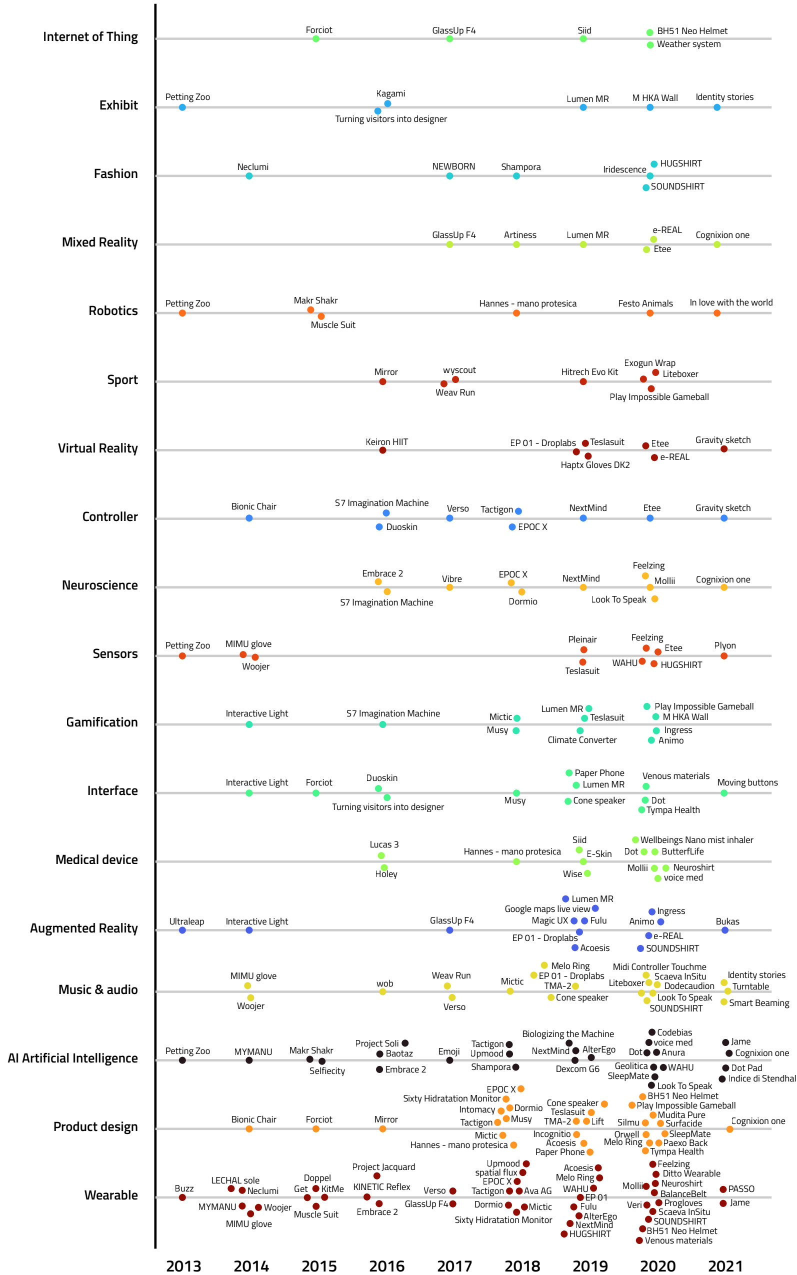
### wob
(2016) *https://adu.unibo.it/hbi/u/70*
152 *experience design, gesture, hearing, music & audio, product design*

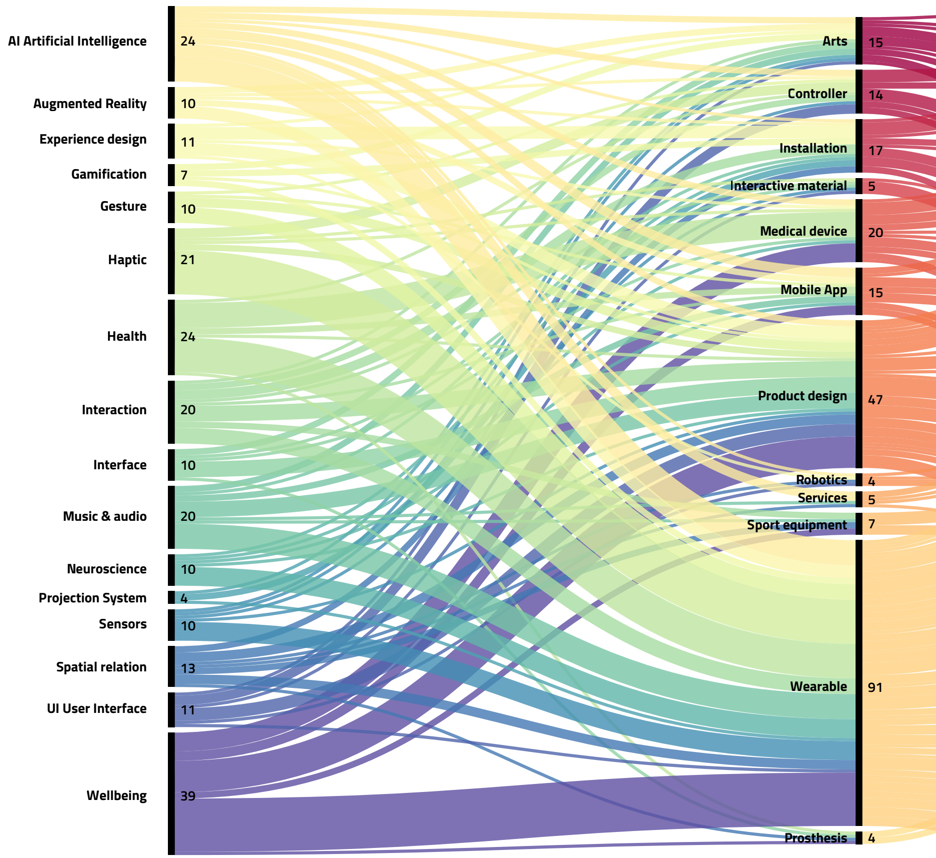
### Woojer
(2014) *https://adu.unibo.it/hbi/u/386*
153 *haptic, music & audio, sensors, service, wearable*

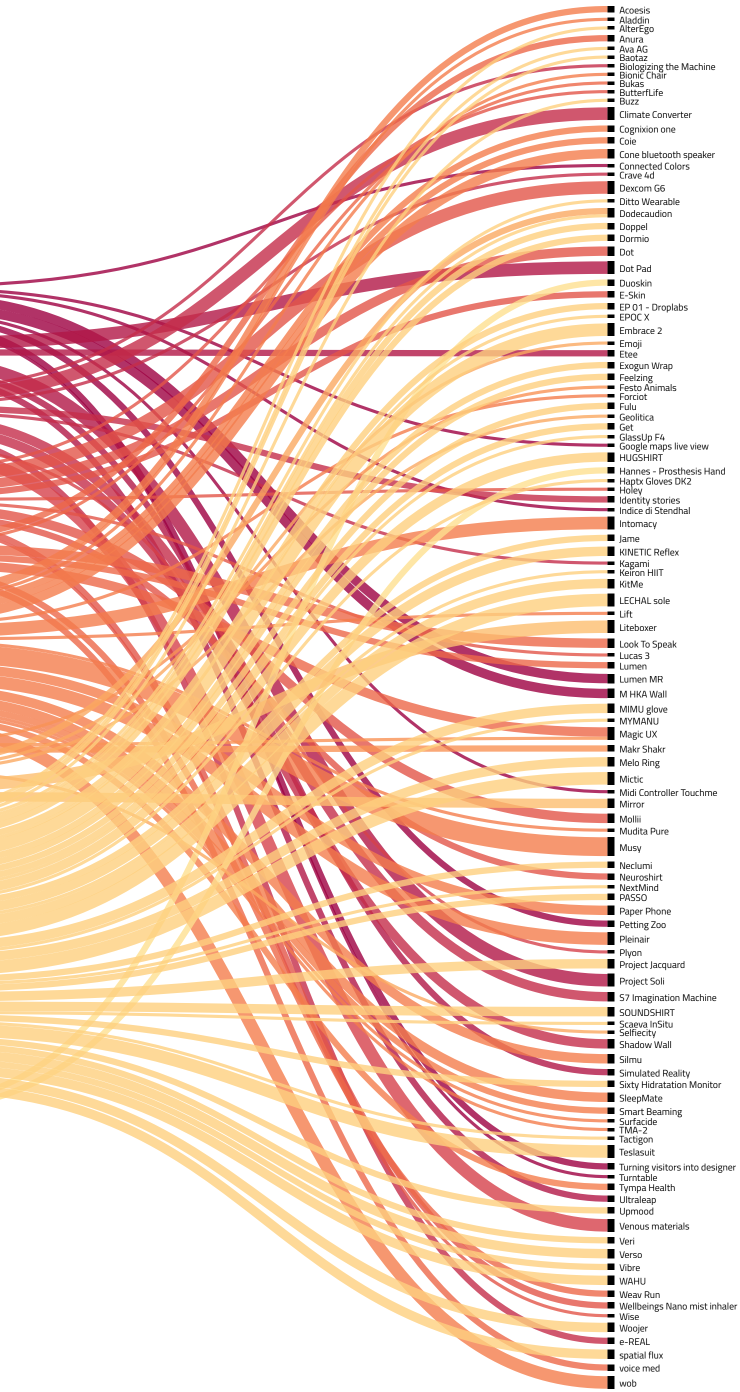
### wyscout
(2017) *https://adu.unibo.it/hbi/u/229*
154 *big data, eye tracker, prediction, proprioception, service*



3. Taxonomy of case studies in relation to the tagging categories (projects published in the book e and available on the observatory http://adu.unibo.it/hbi).


Internet of Thing
Exhibit
Fashion
Mixed Reality
Robotics
Sport
Virtual Reality
Controller
Neuroscience
Sensors
Gamification
Interface
Medical device
Augmented Reality
Music & audio
AI Artificial Intelligence
Product design
Wearable
2013
2014
2015
2016
2017
2018
2019
2020
2021


AI Artificial Intelligence 24
Augmented Reality 10
Experience design 11
Gamification 7
Gesture 10
Haptic 21
Health 24
Interaction 20
Interface 10
Music & audio 20
Neuroscience 10
Projection System 4
Sensors 10
Spatial relation 13
UI User Interface 11
Wellbeing 39
Arts 15
Controller 14
Installation 17
Interactive material 5
Medical device 20
Mobile App 15
Product design 47
Robotics 4
Services 5
Sport equipment 7
Wearable 91
Prosthesis 4




4. Analysis of the main tagging categories in relation to the main typologies of products (projects published in the book e and available on the observatory http://adu.unibo.it/hbi).

# HAPTIC MICROINTERACTIONS, SILENT DETAILS IN HUMAN-SPACE INTERACTION

*Giorgio Dall'Osso*, Marco Pezzi**

## The areas of research investigating the mediation between the body and increased spaces

The contemporary indoor and outdoor spaces that men and women pass through during their everyday urban life are characterized by invisible elements concurring to describe them: Digital Data. Produced by man-made technologies and disseminated in every environment (*ubiquitous computing*), data are increasingly referenced to the places where they are created thanks to geolocation. The space whose identity is in part created by the layering of data belonging to it can be defined as a *digital Agora* (Zannoni, 2018).

The overlaying of tangible realities with intangible ones, within the same place, generates renewed modes of space fruition. The aspects that describe these new modes are documented in research in the fields of *augmented reality* and *mixed reality*. Aspects of these research studies are: body language as an element of control of interfaces (*gestures*); interfaces based on natural languages; displays based on proxemics rules (*ambient displays*); transversal interaction rules of the various types of interfaces (*blended interaction*); how single or grouped data can be enjoyed in a multisensory experience (*data sensification*), and so forth.

A feature that cuts across these areas of research is, inevitably, the human body. In a scenario of continuous dialogue with computers in space, people's bodies must armor themselves (Celaschi, 2016) to adapt to the places they live in.

This continuous dialogue presents risks; the resulting design must be careful and respectful of the cognitive and physical balances of the users.

The risk of a continuous interruption of attention (Matthews et al., 2004) is often present, just as it is easy to fall into planning that is incapable of leaving adequate time for reflection

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(Bagnara & Pozzi, 2014) or to generate an effective memory and knowledge (Han, 2017).

The modalities in which users effectively and efficiently engage with new interfaces are explained in the blended interaction framework (Jetter et al., 2014). The framework reflects on post-WIMP interfaces in which interactions often occur in short times and spaces with more than one user. To design intuitive and coherent interfaces that can consume fewer cognitive resources, the concepts indicated by the researchers are derived from the bodily, spatial, and social experiences shared in each user's everyday life.

Linked to these concepts are studies on *Natural User Interfaces* (NUI) that exploit the personal experience of how people live in the everyday world. Common knowledge of the world and the rules of physics such as gravity, friction, and speed are easily exploited in user interfaces. NUIs use awareness of one's own body's capabilities (Shi 2018) and the principles governing sociality in the different environments in which users live as a further focus of development. NUI research identifies gestures as tools to control digital devices. An application example of this is Project Soli (Lien et al., 2016), which introduces a gesture system capable of controlling ubiquitous interfaces.

Many guidelines for the application of space-integrated interfaces can be found in the field of ambient displays. The related research mainly investigates how displays in space can change their behavior as a result of the actions of people who come into their proximity. The rules of proximity (Hall, 1966) indicate how people use distances as relationship tools and can be exploited in UIs to define the ways and depth in which users intend to interact with displays (Vogel & Balakrishnan, 2004).

Ambient displays mainly linger on screen-based or projected interfaces. Much more rarely (MacLean & Roderick, 1999), research proposes the development of objects that can translate digital information at a sensory level into what some refer to as data sensification (Hogan, 2018).

In the scenario in which humans traverse spaces in which computers, interfaces, and data coexist, designs that can mediate between the body and the space itself become fundamental. Devices that can take on this function could certainly be wearables. This field of merchandise has established itself in recent years and studies have highlighted the characteristics that make them usable. Lightness, good-looking comfort, durability, and effortlessness (Rantakari et al., 2016) respond synergistically to the ability of these devices to integrate into human actions without creating discomfort. How wearables cling to the human body is multifaceted and is often related to the type of function required or the domain in which they are worn (Zeagler, 2017).

In short, the field of research investigating the characteristics of computers and interfaces distributed in the environment is broad, the guidelines are many and point to some avenues being more promising than others. As studies of ambient displays indicate, interactions with computers are often very fast, especially in an initial spatial approach. Therefore, there is a need for an effective study of how these interfaces can dialogue with the body in a simple, fast, and coherent manner.

The perception of the body moving in space is a summation of data collected from all sensory channels. Researching and designing the human/space relationship mediated by technology, therefore, means using an approach that takes into account the communicative potential linked to the various sensory channels, especially in the details of each project. The framework for detailed interactions is the one inaugurated by Saffer: micro-interactions (Saffer, 2013).

The present research aims to build a haptic micro-interaction model applied to human/object interaction within shared spaces with multiple users. The model aims to exploit the possibilities offered by haptic technologies applied to the body to preserve cognitive loads and respect a level of privacy and general well-being in the environment.

## Microinteractions, from visual to tactile input

New interaction paradigms, together with the constant increase in the type and amount of information, lead to a radical change in the design context of physical and digital interfaces.

Technological evolution has stimulated the design of products with communication capabilities that do not stop at the visual component but also encroach into other perceptual contexts. Examples of this are smart home products such as *Amazon ECO*, *Google Home*, and *HomePod*, which through visual and auditory feedback change the way people relate to products and domestic spaces.

The behaviors of objects adapt to user needs, show themselves through increasingly multi-sensory forms, and require less focused attention.

These behaviors, delivered in response or pertaining to particular moments of interaction contribute to defining what Saffer calls microinteractions.

The design of these digital behaviors finds inspiration in the artistic techniques related to the representation of movement in sequences of images developed between the 1920s and 1930s. These techniques, which have progressively evolved over the years, have been used by Disney Studios. Disney, in particular, helped to create what are the first guidelines for motion design: the 12 principles of animation (fig. 1), still used and applied today by various motion designers (Thomas & Johnston, 1995).

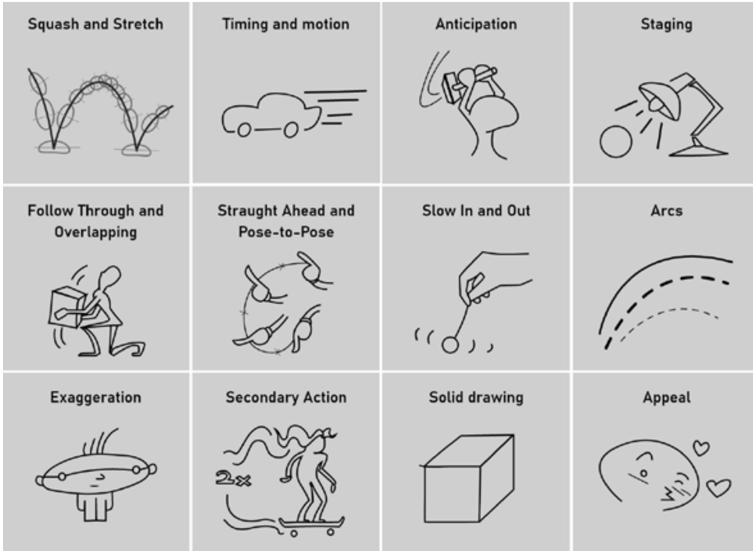
Although these principles were developed and conceived primarily for traditional animation, they have become the basis for more recent computer animation projects (Williams, 2009).

Looking at some of these basic animation principles, we can imagine attributing several of these "characteristics" to a present element in the User Interface to delineate a particular behavior. By analyzing the "Squash and Stretch" principle, we can see that when applied to an element existing in the interface, it can define the rigidity and mass of the object by manipulating and distorting its shape during an action.

In Chang and Ungar's (1993) research, shape changes such as "Squash and Stretch" give objects solidity and offer users selection feedback. "Follow Through" and "Anticipation", on the other hand, create clear, logical interconnections between different interface states. Lastly, "Slow In and Out" provide smooth transitions between them.

Chang and Ungar suggest that with the elimination of sudden shifts, such as simple state changes in transitions, the use of animation improves the understanding of the interface and makes the user experience more appealing. These studies mostly highlight a reduction in cognitive load from the user and a high level of attractiveness from the Graphical User Interface (GUI). These cognitive benefits come primarily from the ability to allow seamless transitions between different states of the interface, making the connections that occur between the previous and the following state immediately clear (Bederson & Boltman, 1998).

1. 12 Principles of animation.




Computer animation effects thus respond to the concept of Natural Language, which uses the physical behaviors of the world to create intuitive tools and comprehensible interfaces.

As the effort to understand these changes transfers from the cognitive system to the perceptual system, the user will be able to focus more closely on the task and become more efficient at perceiving information.

Therefore, the microinteractions that interface objects must propose to users have the potential to interpret natural languages and animation principles to generate effective interactions with low cognitive demand. Adequate use of natural languages can support the user in quickly understanding what is happening in the interface and accompany him or her consistently in the user experience between different interfaces distributed in space.

One of the most studied areas of research is the integration of technology in the areas of ambient displays. Edward Hall's theory of proxemics is often used in this field. In other research studies, the decomposition of the space around the body into the intimate area, personal area, social area, and public area is used as a basis to design interaction at different distances from the interactive display. Vogel and Balakrishnan (2004) identify four areas around each display to which a certain type of interaction corresponds.

The first area is called ambient display. In this area, the displays relate to the architectural space and only communicate their presence in the context through small and slow transformations. These are only meant to communicate their presence concerning the field of perception.

The second area is called Implicit Interaction. In it, sensors and images are reprocessed to accurately understand the situation that is occurring near the display. If the system interprets user behavior as an interest, it transforms itself by implicitly inviting them to approach.

The third area is devoted to Subtle Interaction. Usually, no extended temporality is devoted to it, and the possibilities for interactivity are rather limited.

The last area is defined as personal interaction. This area is the one devoted to more personal or more detailed interactions.

The interactions that occur with displays, whether screens or three-dimensional objects, in the Implicit Interaction and Subtle Interaction areas, are brief and related to simple functionality. The development of microinteractions in these two areas is important in defining good usability.

In the scenario where these interfaces are placed within environments experienced by many people, a useful sensory channel to activate silent interactions that are respectful of their surroundings is that of touch.

The use of the haptic channel for human-machine communication is a broad area of scientific research known as haptics. In it, technological components acting on both touch and proprioception are studied. Haptics is used for multiple purposes (Jones & Sarter, 2008) especially when other sensory channels are already used for primary tasks or when silent or high-privacy communication is needed.

Through multiple types of actuators, it is possible to communicate with the body through both vibration and pressure. Technologies that enable the former have a more manageable volume and are less energy-intensive; grids of vibratory elements are often used to create alphabetic, phonemic (Brewster & Brown, 2004), or emotional languages (Rovers & van Essen, 2004). However, the languages that are most valued by users are those created by the action of pressure (Kettner et al., 2017). The potentials of these stimuli are similar to those of vibration, but the actuators used are much more complex to manage, especially when anchored to and carried by the body (Pohl et al., 2017). The complexity of these stimuli can be very broad by acting on the waveform (Baumann et al., 2010), the materials and geometry of the actuators (Zheng & Morrell, 2012), the rhythm, and the application point in the body (Dall'Osso, 2021).

An interesting intermediate route is a fusion within the same system of both types of stimulation achieving effects such as tapping, entrainment, squeezing, and twisting (Stanley & Kuchenbecker, 2012).

## Haptic microinteractions

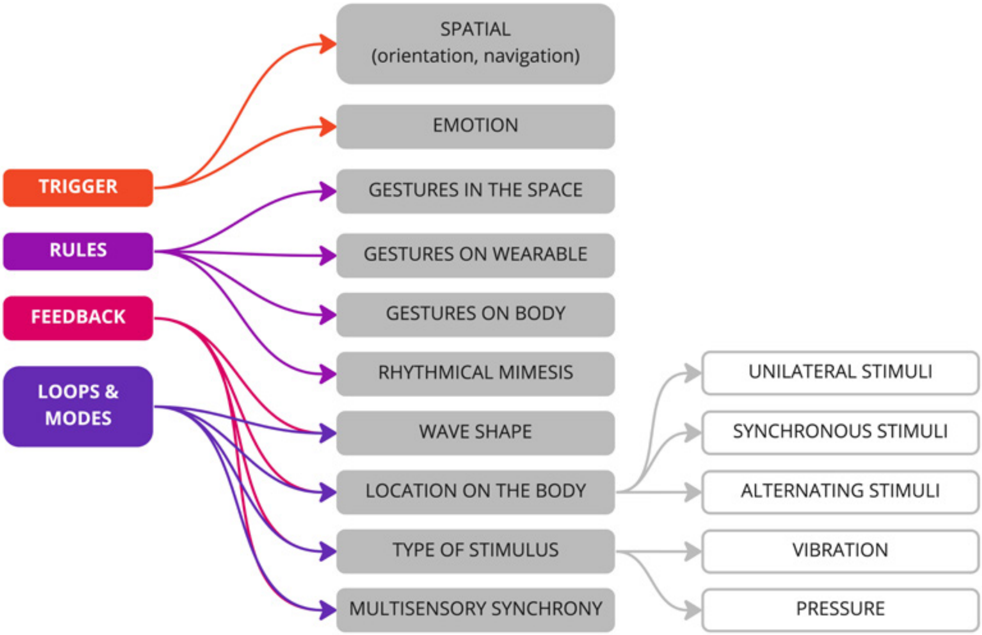
Designers use microinteractions as mediating tools between the body and technology with the task of doing as much as possible with as little as possible (Saffer, 2013).

Microinteractions are structured into five elements:

- triggers (the elements that initiate interactions);
- rules (the elements that indicate how the microinteraction should work);
- feedback (the elements that inform how the interactions work);
- loops and modes (the elements that indicate how the microinteraction will evolve).

The elements that make up microinteractions are studied primarily at the visual level. In scenarios where a constellation of smart and responsive objects appears in the spaces where people live, it is important to reflect on the possibility that wearables can be supports for microinteractions that are intuitive, brief, and at an acceptable level of privacy. Indeed, in these contexts, objects could interact simultaneously with multiple users, and using a sensory channel other than touch could result in annoying and inefficient overlaps. These microinteractions will therefore be important, especially at the time of conscious interaction at a distance from objects.

As highlighted by the literature survey, haptics-related languages seem to back the idea that effects can occur at the skin's surface that support microinteractions. The following sections set out the characteristics and guidelines of the haptics-based microinteraction model within a real space (fig. 2).




2. Haptic
microinteraction model.

*Haptic trigger*

Initiating interaction with an object is an important step, especially in a space where there may be many interfaces that are not immediately visible. Several case studies use haptics to support navigation in urban areas by suggesting directions to a body that is walking (Enriquez et al., 2001; Dall'Osso, 2021) or driving a car (Ploch et al., 2016).

Touch then generates sensations that the body reads by associating specific emotions (Koch & Rautner, 2017). The tactile channel, particularly through pressure stimuli, can therefore be an excellent trigger for interaction as it can shift attention to specific directions in space and predispose to emotions.

The characteristics underlying the creation of triggers are those of haptic stimuli discussed in the preceding paragraphs.

*Haptic rules*

The rules that the body can make available to a natural language-based interaction are mainly found in the research field of gestures. This type of interaction is studied concerning gestures made in space (Lien et al., 2016), gestures made in contact with the wearable (Poupyrev et al., 2016), and finally gestures close to the skin using the body as an interface (Shoemaker et al., 2010). A particular interaction rule can be constructed based on the principle of rhythmical mimesis – i.e., people's ability to reproduce a perceived rhythm. Thus, it is possible to imagine interaction rules that are based on the ability to follow the rhythm of the object one wants to involve.

*Haptic feedback*

In addition to the general characteristics of haptic stimuli, it is possible to send feedback to the body by acting on the complexity of its surface (Karuei et al., 2011). The body, in its symmetrical division into two equal and opposite parts called Antimeres, can be exploited to send synchronous, alternating, or unilateral stimuli (Dall'Osso, 2021). Haptics could then be exploited as a reinforcing tool for feedback that already occurs on other sensory channels using simple synchrony between visual-tactile or acoustic-tactile stimuli (Dall'Osso, 2021).

### *Haptic loops and modes*

Loops and modes of haptic micro-interaction can be designed from the features described in both triggers and the aforementioned haptic feedback. What differentiates them in the experience is their role: in this case, they are neither reminders of the interaction (triggers) nor responses to an action done (feedback). These characterizations are accompanying elements to the interaction that anticipate or emphasize a behavior. The reviewed bibliography does not identify clear elements in the tactile microinteraction model that could describe the difference between these and feedback. Since loops and modes are characterizations that accompany the interaction while feedback is an element of response to an action, it could be argued that the main difference is in their timing: continuous during the interaction for loops and modes, and discrete for feedback.

## Conclusions and future developments

Haptic stimuli offer multiple characteristics that can be used to construct brief and intuitive microinteractions within scenarios in which people are immersed in spaces dense with digital interfaces and data. The model presented, which defines the characteristics of haptic stimuli based on Saffer's five elements, confirms how the haptic channel is of primary importance in the development of wearable objects capable of mediating information in an augmented space.

Future research developments will be aimed at testing the model with specific environmental interfaces in the form of wall displays or with data sets referring to museum spaces.

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# DESIGN OF THE HUMAN BODY: FROM FICTION TO REALITY

*Andreas Sicklinger*, Mirko Daneluzzo***

With us begins the reign of people separated from their roots. That of the decayed man who mixes with iron and feeds on electricity.
Filippo Tommaso Marinetti, *Rinneghiamo i nostri maestri ultimi amanti della luna*, 1917

The wish to improve through technical innovations, but at the same time the fear to lose humanity, goes back to the arts at the beginnings of industrialization. Mary Shelley's novel *Frankenstein or The Modern Prometheus* testifies to this. It appeared as early as 1818 – as a settlement with scientific hubris in the guise of horror romance. During the Renaissance, after a 1000 years of medieval reclusion by the Church, life sciences began to slowly gain terrain, but it took other hundreds of years and brave surgeons to understand more about the human body. A body that was slowly understood as a machine, as the old school of Hippocrates – which analyzed the body only through external symptoms and excretion – was abandoned (Sicklinger, 2020, pp. 32-36). A genius like Leonardo was needed to explore the human body as an interconnected system. His anatomical studies fascinate the observer still today, in part because of their accuracy – when looking at hyper-realistic representations of upper-limb or hand anatomy. But the more impressive sketches are the ones where Leonardo transforms the human joints into mechanical pieces, draws the heart as a 2-chamber oven, or compares a neck with a ship mast to move the head:

> You will make the first draft of the neck with the use of ropes like the tree of a ship near to the coast… Then fix the head with the ropes in order to give movement. (Sicklinger, 2020, p. 40)

Comparison between mechanics and human movement is new and could be interpreted as an ancestor of biomechanics. The human body remains first of all a source of power for work, first in

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agriculture, then in industrial production. The fascination with technology, steam, mechanics, and movement also accelerated the unhealthy interaction of the human body with increasing discomfort, diseases, and losses. Reluctantly, but eventually and necessarily, the human body became an object of research and analysis beyond the pure medical aim of curing, but on a level of possible performance. Many diseases brought by Industrialization and its harmful working conditions caught the attention of brilliant surgeons like Charles Turner Thackrah (1795-1833) regarding the condition of workers, with an improvement in health conditions for a higher benefit of the factory owners (Sicklinger, 2020, pp. 54-57). The fascination with machines, their capacity to overcome human limits of power, precision, and speed, was the basic trend of late nineteenth-century society, together with new communication technologies like the telegraph, colonization, politics dominated by world trade, and coffee house debates.

After 1900, Italian Futurism took this love for engineering achievements to the next level:

> Have you ever watched an engine driver lovingly washing the great powerful body of his engine? He uses the same little acts of tenderness and close familiarity as the lover when caressing his beloved. We know for certain that during the great French rail strike, the organizers of that subversion did not manage to persuade even one single engine driver to sabotage his locomotive. And to me that seems absolutely natural. How on earth could one of these men have injured or destroyed his great, faithful, devoted friend, whose heart was ever giving and courageous, his beautiful engine of steel that had so often glistened sensuously beneath the lubricating caress of his hand? (Marinetti, 1915, pp. 95-96)

questions Filippo Tommaso Marinetti, a self-proclaimed pioneer of the Italian futurists, in 1915 in his book with the incredibly anticipatory title *Extended Man and the Kingdom of the Machine*. His call for self-abolition in favor of the machine was premature, but it produced rousing works of art: the dynamism of new beginnings and the intoxication of speed have probably never been celebrated more euphorically than in the pictures and sculptures with swirling lines of force by Giacomo Balla or Umberto Boccioni.

Ekaterina Lazareva in *The Futurist Concept of Man Extended by Machines* (Lazareva, 2018, p. 215) believes that the erotic metaphors in cited text underline a key Futurist concept: the *extended man* (in Italian: "l'uomo moltiplicato"), who is at the same time human, anti-human, and superhuman. In Marinetti, this concept refers to the strong self-identification of the man with his car, which he eventually proclaimed an "incalculable number of human transformations" (Marinetti, 1915, p. 86) and dreamed of inhuman and mechanical types of human beings who would surpass themselves by means of technical devices. The latter would adapt to the technological environment by growing new body parts: "Even now we can predict a development of the external protrusion of the sternum, resembling a prow, which will have great significance, given that man, in the future, will become an increasingly better aviator." (Marinetti, 1915, p. 86) One could again go back to Leonardo da Vinci and his experiments on a flying machine, where wings are added to arms as extensions and imitations of a bird's anatomy. Underlying experiments and calculations of the arm forces to explain the available force for moving those wings confirm the idea of *mechanizing* the upper limbs.

This love of technology is compared with the daily life struggle with often deadly uncontrolled machines and vehicles simply because of the lack of acquaintance with the new speed and power. Man is threatened by smoking vehicles or electric trams, especially in the fast-growing cities with the continuously enlarging, unconscious population from the land. On one hand, these urban contexts brought a variety of environmental issues such as pollution of water, air, and soil, but also a variety of forward-looking innovations. Municipal water, gas, and electricity companies provided artificial light and flowing water not only in public life but soon also in the private sector, while electric trams allowed to connect more affordable suburban areas to the town center. The technological metropolitan culture became the basis for diverse optimistic visions of progress, but also for experiences of loss of natural life contexts and novel clinical pictures. The nerves of many people seemed to be no longer able to cope with the increasing speed, the noise, and the hectic pace of industrialized society; the neurasthenia disease spread and became the hallmark of an *age of nervousness*.[1] Already in 1869, the New York doctor George M. Beard published an article on psychosomatic disorders in a medical journal and found wide appeal, also in Europe. Those who experienced the last decades of the 19th century were evidently already the victims of new neural deceases as frequent publications on the topic confirm. Nervous weakness as a disorder of the entire nervous system became increasingly common in a such century, according to the large Meyer-Verlag encyclopedia of 1896. Not to be considered an actual disease, but can be seen as a result of the fact that the nerves in the broadest sense are overwhelmed by the growing demands for mental and physical performance. The historian Joachim Radkau believes that the frequent occurrence of nervous disorders appeared mainly around 1880: until then, working life was still largely determined by the natural rhythm but also – for multiple reasons from politics (wars around Europe to establish new political orders and powers) to technology (steam, industrialization, extensive colonization, trading) – got into stormy motion. Time and speed were given a completely different status, complaints increased about the constant need to catch up and not getting the job done. All these factors extended their influence to other life sections. The advancing process of industrialization, the change in eating habits, and the expansion of the sedentary lifestyle resulted in disturbances that quickly became a mass phenomenon.

In 1923, Le Corbusier proclaims *Une maison est une machine à habiter* [a house is a machine in which to live], thus extending the new idea of public life to the personal living space, visually made famous through the epic film *Metropolis* by Fritz Lang in 1927. The Unité d'Habitation in Marseilles is the emblematic example of concentrating living spaces in a reduced volume, with the intent to enlarge the remaining green area, but at the same time neglecting the need for the individuality of human nature. As part of a machine, the single human units should fit into a greater order of engineered living.

What was originally understood as the integration of the machine with the human being for the purposes of innovation and reduced personal fatigue – since the machine can surpass human abilities (especially strength) by a thousand times – soon became detached from the economic interests of factory owners. The human body constantly interacting with the machine became a *mechanical system* in itself, regarded as the place of *smart* mechanical-biological elements. With strong criticism under the veil of satire, Charlie Chaplin accused this late industrialism – where nervous diseases had already been clearly recognized and related to repetitive body movements and inconvenient postures – at the beginning of his film *Modern Times* in 1935. In the famous scenes, in which the actor is under the stress of repetitive movements, the reactions of this suffering mind are various: the restless fixing of bolts at any given speed makes him chase missing items into the mechanical systems of the production, up to the final stage of delirium when he sees a bolt to fix in any kind of bottom. The result is, as shown correctly in the film, a nervous breakdown, and recovery in a specialized hospital.

With the advancement of medicine, what Mary Shelley portrayed as a horror vision became more and more a reality: transplants, repairs, improvements to human organs, and the skills associated with them. But also the mere performance of exceptional actors started to increasingly attract the dreams of thousands: the giant that can’t be defeated if not by unusual smartness (as in the case of David and Goliath) started to become the goal of human power. The idea of exceptional soldiers and workers fires the imagination of ideologies, especially those based on Anticapitalism: the example of Alekseĭ Grigor’evič Stakhanov. On August 31, 1935, he mined 102 tons of coal in one shift of 6 hours in a hard coal mine. That was 14 times the labor standard at the time, which was 7 tons on average. He had previously exceeded this value, but that day was particular. He was hailed as the ideal of a worker. After his record, he became head of the Socialist Competition Department in the Ministry of Coal Industry, but he could not deal with his success: a worsening alcohol problem and ensuing incidents eventually led to an ultimatum to leave Moscow within 24 hours. The social dimension of the phenomenon becomes immediately visible. But in the end, the term Stakhanovism today represents not the socialists’ Party desired success for work improvement, but an insane attitude of work exaggeration, often leading to workaholism (Stacanovismo, s.d.) Yet, dealing with an almost superhuman ability gains particular importance on a social responsibility level,[2] which cinema wants us to believe in the idealized forms of the superheroes like Superman, Spiderman, etc.: the dream of superpowers that characterize the heroes of the new era are more important than the more medieval idea of miracle maker or wizards with supernatural, unexplainable powers. Superheroes, in contrast to wizards, are characters that possess superpowers, abilities beyond those of ordinary people, and fit the role of the hero, typically using their powers to help the world become a better place, or dedicating themselves to protecting the public and fighting crime. These advanced body features made generations of readers and cinema spectators dream of replicating the same body abilities and being admired for their actions. It went so far that in one of the most successful cinema sequels, Arnold Schwarzenegger in Terminator II turns into a good personality, after having been introduced in Terminator I as the undestroyable humanoid robot from the future that wants to determine human destiny. In this way, the personality won the sympathy of the globe.

The spirit of the time of *Human (as) Engines*, highly performing, powerful, and perhaps indestructible, was nurtured by philosophical ideas like the *Übermensch*, which has been translated as *Beyond-Man*, *Superman*, *Overman*, *Uberman*, or *Superhuman*. Different from the idea of Marinetti's *Extended Man*, who is to be modified as a machine or part of it, this (philosophical) superhuman is an *ideal person* who has outgrown the ordinary life of a person who is considered normal and mostly negative. But the scientific progress went much further than the hypothesis of the most famous *Übermensch* by Friedrich Nietzsche, who is able to perform better through *above-average health*. According to Nietzsche, the future person will first and foremost need one thing: *great health* – something which one not only has, but also constantly acquires and has to acquire, because one has to give it up again and again (Virilio, 1996, p. 118). In Nietzsche's *Thus spoke Zarathustra*, the consequence of these statements is well known:

> this brings healthier people, dangerously healthy people, or rather *Übermenschen*, whose reward is to have an as yet unknown country in front of you, the borders of which no one has yet ignored, a beyond all previous countries... (Virilio, 1996, p. 119)

The idea of "sit mens sana in corpore sano" is not new, and body training to improve health is as ancient as Greek and Egyptian stone lifting practices. The ideal body was toned and trained, either as esthetical value or as an image of war performance. Yet the citation of Nietzsche sounds like the end sequence of the 1982 film *Blade Runner*, when the Android declares "I have seen things you people wouldn't believe", pointing out the impossibility of human bodies (and minds) to face certain environments that need stronger bodies: it becomes his claim for the right to live. Paul Virilio calls this the *Planet Man*, a scientifically and universally adapted body prepared for interstellar travels. He analyses in his book *Die Eroberung des Körpers* that the new frontiers of science and discovery are no longer to be sought in the large dimension of the universe but in the extremely small dimension of nanotechnology and, connected with this, the effects and interventions on and especially in the human body (VIRILIO, 1996, p. 120). This is the new frontier of modern science. Instead of the bite of a spider or the breath of an Egyptian Cat that generates a superhero,[3] we ought to think that what is closer to a real future vision of *Übermenschen* is the fictional character Molly Millions from Gibson's influencing *Negromante* from 1984.

> Molly is a physically tough bodyguard/mercenary cyborg. Her augmentations are referred to the lenses [...] sealing her eyes in their sockets; at first glance, they resemble mirror glasses. The lenses are probably vision-enhancing; but do not seem to cut down the sunlight. Microchannel image-amplifications allow her to see in the dark by converting photons into a pulse of electrons. The switch is one of her lower front teeth. While her nails are artificial. Beneath them there are 10 narrow, pale blue steel scalpels 4 cm in length. They are double-edged razor-sharp blades that stick straight out from her fingers. And finally, a clock readout with blue characters is chipped into her optic nerve, low in her left peripheral field. Her sensory input, metabolism and neuromotor reflexes are also artificially [augmented] by means of electronic implants and exotic forms of advanced surgeries and other medical procedures. Even while wearing a plaster cast her movements are calculated, like a dance. (MOLLY MILLIONS, S.D.)

Medical surgeons saw the human body as a designer's object, rather than a place to adjust defects or missing parts, for years, starting first with the aim of maintaining the eternal beauty of the aging skin and body, and later to enhance performance to a higher level.

The teaser of Deus Ex related to the augmented biomechanical technology company, Sarif Industries, alludes efficiently to a new future that handles human bodies like the one of Molly Million. It becomes a matter of personalization of body performance. At this point, the Cyborg is conceived.

The cyborg is a hybrid creature, defined as a state that transcends the limitations of human existence with the help of cutting-edge technologies of different kinds, mechanical or biological, including genetic manipulation, nanotechnology, and robotics. The term *cyborg* was first coined in the 1960s by researchers attempting to adapt the human body for space exploration, who defined it as the entity that "deliberately incorporates exogenous components extending the self-regulatory control function of the organism in order to adapt it to new environments" (Clynes & Kline, 1960, p. 27). This depiction rewrites the connection between humans and technology that has shaped the collective imagination up to that time. From the ab-human Gothic automation (Hurley, 2004) to a post-human condition. Donna Haraway (1991) stated that the cyborg is a cultural metaphor for a hybrid figure (human, animal, machine), able to destabilize the dichotomic forms of the western world, challenging humanist, anthropocentric assumptions. Haraway explored the potential of technology to address socio-political issues such as inequality in class, gender, and ethnicity through the cyborg as a *confusion of boundaries*. Being outside of classification systems and hierarchies, cyborgs represent a way to reject the systems that served as means to dominate certain classes of people. In *The Surrogates*, a limited-edition comic book series by Robert Venditti, humans have the possibility to live their daily lives through other bodies: there is one who chooses a surrogate body to be able to walk; one who wants to be the woman he is in the inside; and one who chooses a surrogate body to access a male-dominated job. These people are all limited by their physical bodies in different ways, and so the surrogate bodies are necessary for them to fully enjoy life. The scenario depicted in the comic book lets us understand that by limiting bodily variation, erasing race and cultural difference in favor of one race and culture, we risk falling into what Hayles refers to as a nightmare, a "culture inhabited by posthumans who regard their bodies as fashion accessories rather than the ground of being" (1999, p. 5). Hayles warns us of the importance of recognizing and celebrating "finitude as a condition of human being, and that understands human life is embedded in a material world of great complexity" (1999, p. 5). Haraway's optimistic view is shared by many, especially the ones interested in the cyborg as a condition of cognitive and physical enhancement. Bostrom and Sandberg (2009), for example, say that humans, with the help of progressive technology, could attain higher levels of moral excellence and become transhuman. This approach is putting at the center the hard modifications through technology, trusting that this will allow us to transcend the limitations and evils of humanity. This approach seems not interested in the social implications related to patriarchal problems, classism, poverty, and racism. It is indeed more utilitarian and grounded in humanist ideologies bringing indeed other issues to the table. On one hand, we have technological devices, think about biomedical devices, that like all computers can be hacked and reprogrammed, opening issues on the violability of the body. On the other hand, we have the problem of the accessibility of these technologies. The risk of limiting the use to a certain elite of individuals and preventing other groups from participating in the potential transformations that cyborg technology could permit has to do with power distribution issues.

The promises of the cyborg culture are something other than what it delivers. Gene therapy, drug therapy, mechanical human-like replacement limbs, and neural implants are mostly in the experimental stage (*ibid.*, p. 312). We are used to a more mundane reality, that contemplates the use of technologies to treat people suffering from physical illness and possibly restore the conditions to that of a healthy person. More advanced cyborg technologies exist only in speculative fiction, for now. The reconceptualization of the human body in a 'techno-body', using this idea of merging the biological/natural and the technological/cultural, has infiltrated the imagination of Western culture (Balsamo, 1996). Different forms of the cybernetic organism have been persistent in popular culture products such as books, TV shows, movies, videogames, toys, and comic books. This dimension is rapidly overlapping with reality, creating a blurred, if not confused territory. This is clear if we think about the ban from the 2008 Olympic games given to Oscar Pistorius. According to the IAAF, the international governing body of track and field, the J-shaped blade gave Pistorius an unfair advantage over able-bodied athletes by allowing him to use less energy as he ran. Dr. Hugh Herr, a professor of biomechatronic at MIT, referred directly to the negative influence of the collective imagination: "One thing we're fighting against is pop culture and Hollywood... People believe things exist that don't." (Springer, 2008, p. 26) This does not mean that we are not going in that direction. Herr himself indicated that “we are beginning the age in which machines attached to our bodies will make us stronger and faster and more efficient” (Herr, 2014), referring to a project of an active autonomous ankle exoskeleton that reduces the metabolic cost of walking. Fiction has the power to direct the desires of these transformations. On the other hand, if we add the accessibility to manufacturing technologies and electronics, we can certainly see positive results considering, for example, the current possibilities of 3D printing to make prosthetic limbs (The Guardian, 2018, 3:52). When you have the possibility to explore multiple ways to reconstruct your abilities and physical condition, you can recognize the possibility to express new human configurations. Jason Barnes worked to customize his prosthetic forearm to let him play the drums, or to do what he was able to do before his injury. Where there was once a stigma, amputees are now empowered and enhanced. Using a robotic arm designed to collaborate in the performance, Barnes can now play the drums in a way not humanly possible, thus becoming a *bionic musician* (Freethink, 2018). Victoria Modesta – a model, singer, and performance artist – started a new identity as a bionic pop artist. She proposes a new way of thinking and perceiving disability and altered beauty (Lant, 2017), where prosthetic technologies are not perceived as something to hide, or something separated, but instead something to design as cool and glamorous augmentations. Are we continuing Hayles’ nightmare? Not if you consider that these are tools reinforcing identities. Instead of being ashamed or embarrassed, technology could help transform not only the everyday reality but also the perception of the self, and push even more questions on what else could be done to explore new bodily configurations, as said by Angel Giuffria in an interview for *The Guardian*: *What if I don’t want a hand, what if I want a tentacle?* (2018, 0:21). The preparation for this shift partially comes from science. In 1998, cybernetic professor and biomedical engineer Kevin Warwick famously installed a microchip into his forearm that connected him to the internet, allowing him to control electronic objects, and thus explore a dimension of *the other*. Part of this comes from art. Stelarc, in the *Third hand* project, added a prosthetic mechanical hand to his own biological body: a third limb independently controlled by nerve impulses from surface electrodes attached to his body. We can re-design the body for other ways to act in the world, beyond our regular experience. Enhancement therefore not only allows us to be faster or stronger but also lets us do something we were not able to do before. Design and art, besides fiction, are ideal contexts where to explore also extreme scenarios of transformation for the distant future. Michael Burton and Michiko Nitta developed an energy-related post-human scenario, with the project *The Algaculture*. Inspired by research on photosynthetic creatures conducted by Debora MacKenzie and Michael Le Page (2010), the Human body is enhanced with algae living – and serving as an alternative fuel – inside new prosthetic organs. The cyborg here becomes again an occasion for challenging anthropocentrism and human exceptionalism and emphasizes our co-dependency with nonhuman life, producing new corporeal entanglements and mutual cooperation to reinvent ourselves on an interconnected changing planet.

Again, fiction goes far, reality makes one step at a time, but both are important in this feedback loop to construct our human condition. We start to see products in the market for body augmentations like NeuroSky's prosthetic toy limbs: the Necomimi cat ear set. It is a headset of mechanized ears using EEG sensors to let the ear react according to the brain activity, extending emotional expressivity. If you are focused, the ears tend to perk up and move fast; and when you are relaxed, the ears droop. Devices like this are still a niche gadget, not adopted on a massive scale to have a direct impact on society, but what if we can easily wear something like this every day to enhance our body language? How would this change social interactions? We are experiencing these changes faster and faster. In the early 2000s the idea of *sousveillance* (Mann et al., 2002) was introduced: a reverse-Big Brother where ordinary people would use wearable cameras and other technologies to keep watch on companies and governments. Examples include citizens recording police brutality and sending the footage to news media. We do not wear cameras yet, but if you think about it, this is the reality of our days, thanks to our smartphones and the network connecting them. Considering contemporary industrialized cultures, the integration of technologies is not only common but necessary for everyday life. Our bodies must work in harmony with machines, hardware, and software that, in one way or another, become a part of us.

The leaps that fiction allow, the distance between us now and in the future, carry the questions about what we are going to lose in the process, in this distant journey. With fiction we design possible futures and question our condition and our relationship with technology and our ability to modify ourselves. This relationship has been explored with an interesting twist in Paul Verhoeven's *RoboCop* (1987) and its remake by José Padilha (2014). It is the story of a Detroit policeman who is badly injured and subsequently given an almost entirely prosthetic body. The organic/natural part is limited to the human face, the brain, and the spinal cord of his central nervous system. In Padilha's version he also has the lungs and a hand. This extreme condition forces us to ask ourselves if RoboCop is still human after this heavy transformation, proposing again the Frankensteinian ab-human concept. In addition it seems that the human-technology relationship is inverted: the human part is more a prosthesis of the robotic body rather than the opposite. Without the human part, technology risks of being subject to tremendous mistakes, like when the ED-209 malfunctions and kills one of the OCP managers. As they differentiate the human identity from the post-human, the films engage with questions of how the biological and technological characteristics of the protagonist impact his detective skills, crime-fighting, and masculine gender performance (Marsellus, 2017). In Verhoeven's movie, the transformation of Murphy into RoboCop consists in losing his physical self, his memory, and mental faculties, but also his entire human identity as Alex Murphy (*ibid.*). In short, in the words of Bob Morton, junior executive of OCP, "he doesn't have a name, he's got a program, he's a product". This new body is sculpted like a hyper-muscular human body with large pectorals, well-defined abdominals (*ibid.*), and defined shoulders. He is basically a robot with a human face, his movements are extremely precise but mechanical and slow, you feel the time to process the action, and it is something that as a spectator you see through his visor that shows the linear logic of the actions and their computations. These traits make him very efficient as a crime fighter, but he completely lost his detective skills: he is shown patrolling and stopping when and where the dispatcher tells him to go. In Verhoeven's critique of the post-human, "To eliminate weakness and become a perfect hyper-masculine fighting machine, one has to actually become a hyper-masculine machine, sacrificing talent in detecting crimes for an indestructible power in fighting them" (*ibid.*). This changes when the humanity of Murphy emerges in the form of dreams and memories of his family. This acts as a trigger for a behavioral transformation, from the fighting machine that executes commands, to a human-driven detective that begins investigating his past. His body makes it able to efficiently fight crime and his human mind is effective in detecting criminals, but he is fully hampered by the systemic corruption embedded in his programming (Telotte, 1991, p. 17) – which, for example, prevents him to harm OCP employees. Padilha's version tackles the transformation of Murphy into RoboCop from another perspective. The technology comes from neurorobotic prosthetics designed for injured people, and they make it clear from the beginning what they think makes a human: "You are not you because of your legs, your arms, your hand. It is your brain capacity to process information that makes [you] who you are" says Dr. Dennett Norton to a patient that is testing his new robotic arms for the first time. We are adaptive beings, because our brain has the capacity to adapt constantly to different conditions, and its plasticity gives us the capacity to embed technology in an extended sense of the self. Murphy, as we said, wakes up in a condition where the prosthetic part of his body is dominant, leaving just a few organic parts from his human condition. What he thinks at the beginning is a suit is, instead, his new prosthetic body. This new reality is understandably shocking for him and difficult to handle psychologically. We know he is supposed to be a fighting machine, but the human, mental control makes him less efficient in combat scenarios, so to improve his performance, they computerize his brain so that any sensation of danger triggers the computer to take over his actions, giving him an illusion of free will. It is not a man in or extended by a machine, but as the OmniCorp executives say, "it's a machine that thinks it's Alex Murphy". The human part has the ability to construct sense, but it's limiting the efficiency of the execution. When the visor comes down, he is indeed transformed into a fully automated and emotionless drone. Padilha's RoboCop is a cyborg in the age of information networks (Sudlow, 2015). He has an extended perception, where the city itself becomes an extension of his body, an additional sensorial apparatus, a prosthesis of the prosthesis, with a corporeality of another scale, that again, like in the previous and other movies, is visualized as a visualization of augmented reality would. The reality that you perceive in that specific time and space is just one of many. The speed of connectivity that his new body offers allows him to access police records, CCTV databases, and live feeds, to shape his tactical and strategic actions. RoboCop sets lists of criminal targets and completes his goals with extreme efficiency; you have the feeling of facing an infallible machine representing the infallibility of automation and advanced surveillance. Thus, in this version of the movie, the detective skills are multiplied by a cognitive enhancement. In Padilah's *RoboCop*, the human component can even reverse the changes made to his neurotransmitters, making the coexistence of the human and robot elements harmonious and pushing him to overcome the programming that should have prevented him to harm the OmniCorp CEO. The alteration made to control his behaviors allows him to bypass his robotic restrictions. The combination of technology and humanity are the elements to reclaim his autonomous cyborg identity (Marsellus, 2017). The cynical satire of Verhoeven where "no mix of humanity, masculinity, and technology result effective crime-fighting" (*ibid.*) is different from Padilha's optimistic humanism where technology is effective, is a positive force, and corruption is outside his body, outside technology, because the human part is in control.

> Literary texts are not, of course, merely passive conduits. They actively shape what the technologies mean and what the scientific theories signify in cultural contexts. They also embody assumptions like those that permeated the scientific theories at critical points. These assumptions included the idea that stability is a desirable social goal, that human beings and human social organizations are self-organizing structures, and that form is more essential than matter. (Hayles, 1999, p. 21)

In a world going towards automated and interconnected technologies, we are probably not interested anymore in what we can lose in the transformation, but instead, what we can give to the technological apparatus to make it more human.

### Notes

[1] Inspired by the book title: Radkau J. (1998). *Das Zeitalter der Nervosität: Deutschland zwischen Bismarck und Hitler*. Hanser.

[2] The widespread character of the muscular hero (from Steve Reeves to Arnold Schwarzenegger) featured in more and more cinema successes from the 1930s on.

[3] Marvel's Spiderman and DC Comics' Catwoman.

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# TOWARDS A RESPONSIBLE PERSPECTIVE IN DESIGN FOR HUMAN BODY INTERACTION. REVIEWING THE ITALIAN DEBATE OF THE EARLY 1970s THROUGH THE DESIGNERS' WORDS

*Elena Formia**

In their investigation of interaction design as a frontier for experimenting the relationship between the human body and the machine through the perspective of Digital Technologies and Key Enabling Technologies, Michele Zannoni et al. (2021) identified three areas encompassing present and future trajectories in the Human Body Design research field: Homo Faber, "the creation and construction of tools;" Homo Saluber, "the incessant search for well-being;" and Homo Cogitans, "the environment based on the use of data and information systems."

Such concepts, the outlined pathways, and the questions they instigate have inspired a research itinerary that generates further food for thought. What are the theoretical implications behind the identified categories? Is the concept of *homo* and *human* still the only cornerstone for the construction and reconstruction of an interpretation of the body-machine relationship? How have the design actors performed within a historical scenario characterized by the advent of digital technologies?

These questions give rise to the need to document, although in a just sketched form, how the Italian design cultures have witnessed, reacted, and at times contributed to define the interpretative models of that which Vittorio Marchis (2005) defined "a century of future," namely a century (the Twentieth) marked by the accumulation of innovations and inventions. Can we identify an autonomous space for action for design and productive thinking (Celaschi et al., 2020) within the alchemy of knowledge, processes, and learning models to systematically investigate in order to understand the complex interactions between the body, machines, humans, technology, and the digital world?

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## A possible incipit. Annus mirabilis 1970: Signs of change

In 1970, Alessandro Mendini was appointed editor of the architecture and design magazine *Casabella*, which progressively became a dominant platform for the discussion of radical design, affirming a critical and ideological stance against consumer society and the role of professionals within it. An institutional magazine founded in 1928, it became – under his directorship (issue 349, 1970 to issue 412, 1976) – a part of the "radical media," attracting many of the most influential figures of the time. In the meantime, other professional trade journals (such as *Domus*, *in. Argomenti e immagini di design*, born in 1970, and *Progettare inpiù*) became advocates of the "new wave" of radical design (Rossi, 2014); while the more "conformist" – evoking Ambasz's definition in 1972 – magazines (*Abitare*, *Ottagono*, *Interni*, and *Casa Vogue*) lived a period of growth and consolidation (Formia, 2017).

In the same year, Tomás Maldonado, the head of the ULM School of Design until 1967, published *La speranza progettuale: ambiente e società*, or *Design, Nature and Revolution: Toward a Critical Ecology*, a brief but dense, speculative, and frequently quoted portrait of the environmental crisis, practically rationalistic and contextually anchored to a radical reform of socio-political systems. The book was conceived during his time at Princeton University (1967-1970), but strictly linked to the work done together with Gui Bonsiepe, who dedicated an issue of the ULM magazine to "environmental design" on the occasion of Maldonado's departure (Warmburg, 2017). The political dimension of the concept of "concrete utopia" presented in the book denotes, according to Simon Sadler (2013), a form of "general, vague, left-leaning 'critical consciousness' as a sufficient 'praxis'." (p. 49)

Italian design élites shared an interest in the environmental field, albeit from differing perspectives, in the First International Biennial of Global Design Methodology, *Le forme dell'ambiente umano* [The Forms of Human Environment], held in 1970 in Rimini. The event's influence on design culture is almost unknown. It was organized by the Pio Manzù International Research Centre (a non-governmental research organization of the United Nations, established in 1969 by Gerardo

Filiberto Dasi) and documented in the magazine *Strutture Ambientali*. The event consisted of ten days of talks, round tables, and exhibitions attracting institutional representatives and leading figures of the professional, critical, and academic world. Coordinated by a managing committee of international caliber – including Giulio Carlo Argan, Luciano Anceschi, Gillo Dorfles, Franco Ferratotti, Maldonado, and Bruno Munari – the event gave also space and shape to cybernetics theories as well as forms of interaction between human and computers (Formia, 2019).[1]

This essay starts from a temporal (the early 1970s) and contextual (the mediating space represented by magazines, exhibitions, conferences, and temporary events) definition to reflect on the Italian cultural debate through the words of those actors involved in combining design challenges with paradigmatic changes concerning the human-nature-artificial-technology relationship. Some of the factors affecting the general context were: the increasing popularity (in Italy) of systems theory and cybernetics applied transversally to different areas of knowledge, especially thanks to the interaction with the US culture and counterculture, from future studies to Stewart Brand, passing through the active role of Aurelio Peccei (Peruccio, 2014); the rise of a shared interest in the impacts of human actions on natural ecosystems, manifested by both the ecological current and the politically-based environmentalist movements (Fallan, 2014; 2019); the development of a manufacturing culture of excellence (e.g. the Olivetti Programma 101 was the first-ever desktop calculator, developed between 1962 and 1964); the close connection between design, utopias, freedom, and cultural policies, with implications on professionals' commitment, participation, and social responsibility (Dellapiana, 2020).

## Proposal for an anthology through four perspectives

By referencing the writings of four actors belonging to the research world of the 1970s, the text hereinafter provides a possible basis to interpret the interaction between design cultures, the body and technology, in an attempt to find roots, touchpoints and shared perspectives. The essay does not simply set out to contextualize the works presented. It intends to extrapolate four points of view that, on different levels, seem to have oriented a discussion that has broadly developed in the following two decades, when graphic design, communication design, and user analysis skills would expand to the field of software, allowing designers to enter the human computer interaction sector (Formia & Peruccio, 2021), in parallel with the consolidation of key concepts and logics such as "cyberspace" (Marchis, 2005, p. 298), "digital revolution", dematerialization, and "gamification" (Baricco, 2018).

Nevertheless, the presented periodization does not overlook a reasoning on the deep roots of such relationship (Celaschi, 2016; Casoni & Celaschi, 2020), as claimed by Beatriz Colomina and Mark Wigley (2016) in the short but intense book *Are we human? Notes on archeology of design*, in which the authors see the need for body redesign and modification as an anthropological constant in the history of mankind. Their transversal notes on 20th century modern design interpreted in the light of the overlap with medicine, health, and personal care, are quite interesting. The authors wrote:

> For the Eames, as for Le Corbusier, the designer is a surgeon. In the course of an interview, Charles Eames said: 'The preoccupation with self-expression is no more appropriate to the world of art than it is to the world of surgery'. […] The modern body housed by modern architecture was not a single body but a multiplicity of bodies. The body was no longer a stable point of reference around which an architecture could be built. Architects like Le Corbusier and his colleagues actively redesigned the body with their architecture rather than housing it or symbolizing it. (Colomina & Wigley, 2016, p. 118)

By saying this, they meant not only the body in its physical dimension, but even in its psychological form, thus agreeing with the newborn psychoanalysis and psychiatry theories. In the meantime, the close link between design, body, and machine was strongly affected by the human-centered design approach, pioneeringly launched in the era of modernism, but theoretically established in the years of the Western economic boom, with a growing focus on consumer demands.

Nonetheless, as mentioned in the introduction, signs of change may be identified in the 1970s. The excerpts from the texts quoted hereinafter focus on the topic of the body as the object and subject of design, but also show a growing interest in new technologies and the relationship between humans and computers, without ignoring the advent of a groundbreaking ontological approach that questioned responsibilities towards the Planet, also by criticizing the technocratic pragmatism.

The excerpts state – also through explicit cross-references – four perspectives that are, in turn, able to provide food for thought and topics that are still open today.

The proposal is based on the review of canonical and cutting-edge journals; methodologically, it forms part of a field of study that has rediscovered, through the concept of "mediation" (Lees-Maffei, 2009; Dalla Mura & Vinti, 2014), the role of institutions, awards, exhibitions, and magazines in design history. It is in these contexts that pioneering concepts are expressed and thoughts materialize at the same time as the debate is taking root, thus revealing the most advanced frontiers of experimentation and research.

Anthology 1. *The body as a tool*[2]

From: "Global Tools – Body Group. Report by Andrea Branzi, Gaetano Pesce, Alessandro Mendini, Franco Raggi, Ettore Sottsass, Jr. 8 October 1974", in *Global Tools Bulletin*, issue 2 Body/Corpo, 1974.[3]

*The human body [is] analyzed prior to the definition of functional ends, prior to the action of cultural filters, prior to constraints inside the rigidity of systems.*

*The body [is interpreted] as a primary tool. In conventional learning processes (ways through which to systematize experience through notions), the body is seen as impediment or in any case as a factor that can be overlooked, whose awareness of use can be neglected. The body in religion is experienced as a fault, while freeing ourselves of its physical nature becomes a goal.*

*In the process of de-intellectualized actions we can see the body as a tool, apart from a specific culture of the body, simulating and retracing the process that leads progressively from discovery to recognition, to purposed and non-purposed use of one's body.*

*The cognitive result is not predictable, but can be determined a posteriori, after the operations; for example, cognitive processes of* *greater awareness can be triggered regarding the use and the purposed possibilities of one's body, through a negative use of that body.*

Anthology 2. *Ubiquitous intelligence and extended reality*
From: Silvio Ceccato, "Utopia, futurologia e scienza. L'utopia e l'uomo del futuro" [Utopia, futurology, and science. Utopia and the man of the future], in *in. Argomenti e immagini di design*, year II, issue 1, January-February 1971, p. 75.[4]

*Everything will be communicated everywhere, at decreasing costs and increasing speeds. In this way, even the populations that have been independent for millennia shall gather and meld, traditions will dissipate, and the mind will come out discombobulated. Is this massification or individualization? I believe that both sides will benefit, at least when given the choice, in that if everyone receives common information, people may choose the portion they prefer and thus develop their uniqueness on its basis. I shall now touch on a topic I care about, as it responds to one of my expectations or even advice. Humans of the future will, or can, do things out of pleasure that they once did out of duty: this expands the spectrum of their freedom and reduces that of their needs. We owe this to automation and new communication tools – the former replacing us in certain tasks, the latter allowing us not to move but still take part in the things we are interested in. This implies that we may still perform the activities in which automation has replaced us, but optionally and whenever we enjoy performing them. Such activities may include occasional cooking, grocery shopping, sewing, washing clothes, traveling, working the land or gardening, etc. Manual operations may remain the same, but it is the attitude towards them that has changed: an antithesis between work and play, economy and gratuitousness.*[5]

Anthology 3. *Programming*
From: Leonardo Mosso, "Presentazione dei gruppi, 1° Biennale Internazionale di metodologia globale della progettazione 'Le forme dell'ambiente umano', 20-30 Settembre 1970, Rimini, Guida Programmatica" [Presentation of the groups, First International Biennial of Global Design Methodology, 'The Forms of Human Environment', September 20-30, 1970, Rimini, Programmatic Guide], in *Strutture Ambientali*, issue 4-5, 1971, pp. 28-29.[6]

*Our research and in general the research on programming theory as structural self-programming of the Cybernetics Research Center of the University of Turin lie in this alternative framework of popular self-awareness for the development of a common design language. Local programming is thus a special moment of the human design process carried out directly and without mandate by the dwellers of a certain area and following a specific rejection of the mandate for culture and design. Yet, to be fully alternative, the tools of such self-programming can only blossom from the refoundation of all human sciences that – based on a negation of the origins and of their academic reality and their confirmation of authority and support to the elite – may produce the tools and knowledge not only at everyone's service but that may – by nature – be used above all by those most exploited. In modern society and at all stages of human cohabitation, such a global revolution is no longer a moral imperative deriving from the demand that all men shall live as equals but has become a non-deferrable historical imperative and a matter of survival. In fact, the mechanisms of the elite class of men exploiting men or – though with different ramifications – men exploiting nature has led the artificial setting of humans to rest in last-chance conditions: those immediately preceding the ecological catastrophe.*[7]

From: Leonardo Mosso, "Tema generale di lavoro del gruppo: nuova ecologia, programmazione territoriale come equilibrio di autogestione nel sistema ecologico uomo-ambiente" [General topic of the group's work: new ecology, territorial planning as a balance of self-management in the man-environment ecological system], Allestimento di Bruno Munari, struttura di Leonardo Mosso [Setup by Bruno Munari; structure by Leonardo Mosso]. Coordinatore [Coordinator] Leonardo Mosso.[8]

*In an idea of new ecology, thus new politics, in which everyone has the same decision-making power, the variability and orientation of stochastic constraint laws are determined by common choices. Within such laws of probability and in accordance with the predetermined constraints of all processing cases, the infinite possibilities of individual choices may perfectly correspond to individual vocations, though harmonically included in the common inclination. The calculator thus seems – when it is managed in a shared and democratic way – the only tool able to dominate the enormous complexities* *of individual and common demands, memorize them, and compare them to find compatibility: a true self-programming instrument.*[9]

Anthology 4. *Anthropocene and responsibility*
From: Gui Bonsiepe, "Ecologia e Progettazione Industriale" [Ecology and industrial design], in *Futuribili*, year V, issue 39, October 1971, pp. 25-36.[10]

*We must add to the six definitions mentioned among the goals of industrial design a tendency, recorded at the end of the past decade: industrial design as a means of fighting environmental deterioration and improving our quality of life. At this point, we should ask ourselves whether or not industrial design has reached a turning point and if we can reconcile the six aforementioned goals with the aim of an environmentally oriented design. […] In such a system, man's main goal will be to create positive feedback to oppose the currently prevailing negative feedback. Yet, to set up a relationship with nature distinguished by the positive feedback we must create and spread ecological awareness. […] That which we proudly call a 'scientific and technological revolution' has intruded into our Earth's ecosystem rashly and without worrying too much about the future. […] Every futurology that contemplates the technocratic view is a sort of applied utopia. Yet, technocratic utopia lacks the most important ingredient of the utopian philosophy: hope as a motivational and dynamic force in speculations on the future. Technocratic utopia is thus hopeless: a utopia lacking utopia. […] If we interpret this statement as an invitation to technological abstinence, we should assign it a different meaning: the new technology of post-industrial society should be based on ecological principles, thus must be an eco-friendly technology with positive feedback rather than a negative one, as occurs today.*[11]

## Discussing design, the body, technology, and the future

Reading the excerpts contributes – although in part – to defining thoughts that are not antithetic, but not even complementary: the texts deal with different ways of viewing design in relation to new media, information-digital technologies, and the environmental crisis.

In the first interpretation offered by the Global Tools collective – which was related to the counterculture and climate of protest of the time – the body, which is detached from the functionalistic dependence on the artifactual world, becomes a subject of study and primary tool in itself. It is so that a reflection on the anthropological nature of body-related design is reinstated. Such rediscovery occurs through a rigorous and equally arbitrary process of "inventorization" of its parts, its movements, its positions, its limits, and the multitude of experiences related to it. In this sense, the aim is to create unexpected relationships between bodies, objects, and environments, until the decomposition of the design outcome. From an operational perspective, the actions of the "body" workgroup include the design of objects with limited functions or even malfunctioning, to initiate an investigation leading to a sort of inverse ergonomics or eccentric design anthropology. The standard concepts of use and function are thus overturned and the bodies – disassembled in parts and according to primary needs – become tools in themselves. This paves the way for new fields of investigation and interpretative categories of the body, such as construction ("the body as tool"), theory ("the body as container of the mind"), survival ("the body as energy"), and communication ("the body as transmitter and receiver").

Beppe Finessi (2009) proposed to interpret the focus of Alessandro Mendini – the group leader – on the human body along three main trajectories: designing with the body, designing for the body, and designing bodies, thus anticipating in "these […] bubbling years of fiery gestures, […] the very best premonitory signs of the lustres to come, in which the body would receive more, softer and lighter attention, more strictly functional." (p. 278) It is therefore not surprising how there was a widespread and renewed attention to the body as a privileged subject-object of design. The anthropological exploration is paired with a gradual attention towards the augmented sensory dimension of design that looks at the relationship with the artifactual world as "a genetic mutation that the rise of new media has produced […] in society. […] While the perception of modern humans was analytical, mechanical, that of current humans is synthetic, electronic, auditory." (Branzi, 2006, pp. 106-107). In the same years, experiments focused on forms of "sensitive skins," as proven by the *Dressing Design* clothing system presented by Archizoom and published in issue 373 of *Casabella*, January 1973, or the prototypes by Nanni Strada and Clicio T. Castelli, published in issue 387 of *Casabella*, March 1974, that consider accessories as meaningful prosthetics to sharpen sensory dimensions, later developed with the rise of the so-called wearable technologies.

Oppositely, perhaps only apparently, there was an interest in emerging IT, as the second text testifies. Its use fascinated designers and intellectuals interested in design cultures, in a game of references and associations. As the great international and national corporations (Univac, IBM, Olivetti) developed the first PCs, the topic of programming languages also attracted attention in the form of an exciting stargate to the future, creating strong connections between cybernetics and futurology. A recent MIT study investigated the relationships in the fields of cybernetics, IT, systems thinking, design, and counterculture in the USA (Turner, 2006). It resulted in the *Social Graph of Cybernetics* (Dubberly & Pangaro, 2015), whose aim was to prove that "Cybernetics is 'deeply inter-twingled' (to borrow Nelson's magical phrase) with the early development of personal computers, the 1960's counterculture, and the rise of the design methods movement, which has enjoyed a recent rebranding as 'design thinking':" it is not surprising to read about cross-references between the *Whole Earth Catalog* and the writings of Richard Buckminster Fuller, with references to Christopher Alexander's *Notes on the Synthesis of Form*, Herbert Simon's *Sciences of the Artificial*, Ludwig von Bertalanffy's *General Systems Yearbook*, Norbert Wiener's *The Human Use of Human Beings*, and to the classics dealing with design and cybernetics including works by John Chris Jones, Victor Papanek, Ross Ashby, Warren McCulloch, Nicholas Negroponte, Lawrence Halprin, Gyorgy Polya, and George Miller.

The implications on the Italian culture are instead less known. Despite the repeatedly documented intersection between Stewart Brand's *Whole Earth Catalog* and the Global Tools experience, other episodes prove the emerging theoretical attention towards such topics, but also a desire for applied experimentation especially in temporary or exhibition contexts. The 1970 Rimini Biennale episode is emblematic (Formia, 2019), and the third quotation is related to that context. In particular, the workgroup focused on "Territorial planning as the balancing element in self-management of the human-environment ecological system" presented the preliminary outcomes of the research that led to the "global automatic design model for self-programming of communities:" a "cybernetic system for local planning and for the control of complex forms in art, architecture, and urban design" developed by Leonardo Mosso with Laura Castagno and the CNR (Italian Research Council). This was a methodological and practical approach led by Mosso, the only Italian at the *International IEEE Conference on Systems, Networks and Computers* of Mexico City in 1972.

While, on one hand, the value of the body is rediscovered and, on the other hand, there is a realization of the potential of new IT and digital technologies, we deem it necessary to introduce a third and final dimension that perhaps harmonizes both visions: the growing ecological awareness developing in design culture, in parallel with the consciousness of human social responsibilities towards the environment. It was a moment of great open-mindedness in which the link between systems theory, complexity theory, cybernetics, and ecology seems to anticipate the concept of Anthropocene, introduced in 2000 by Paul Crutzen. As documented in the fourth text, the human being becomes part of a system, molds reality beyond the artificial, has generative and organizational powers. Systems theory and political theory are complementary approaches to studying the destiny of nature and society.

How may we act on the inborn interdependence distinguishing the world of living beings? Design can, in short, exert a technical power to improve reality, it can affect the human-environment relationship, and can provide answers by reinventing the complex cohabitation with the world of machines and technology. These principles underlying the interaction between body, technologies and design are elaborated in a specific historical moment in which the global crisis is combined with a desire for an involvement of the professionals in response to a new type of complexity in mass society. Topicality of them is an evidence, however, the changes of the very idea of society, culture, technologies, and knowledge processes, is giving rise to new paradigms. The main one that marks a clear evolution concerns the human dimension of the body with implications on notions such as cyborg, posthuman, more-than-human, useless bodies. A perspective that reverses points of view: the prerogative of human body interaction is now under discussion since the idea of human itself is no more universal. Using Laura Forlano's words, in commenting the *Arendtian Lexicon*,

> In decentering the human condition in the field of design, such concepts make space not only for the consideration of our complex relations, networks, and assemblages with technology and things but also for the ways in which we coexist with natural environment. In coexisting with technologies as well as with the natural environment, it is beneficial to think of how [...] we might draw on practices of maintenance, repair, and care for making and remaking lives and worlds. (Forlano, 2021, p. 295)

**Notes**

[1] Most of the work presented involved the combination of three interdisciplinary research groups, which had been established in 1968 and revolved around "Free Time and Environmental Structures," "Regional Planning as the Equilibrium of Self-Management in the Ecological System Between Mankind and Environment," and "Organization and Communication in the Operational Space." Two installations were emblematic: the Univac 1108 computer, or an "electronic processor" that interacted with the public based on their hobbies, while another computer played music and a "mechanized museum" by Herbert Ohl involved the audience in an immersive space; a system of self-organization and co-design of territories and collective spaces, presented by an Italian group working on "Regional Planning" led by Leonardo Mosso.

[2] The titles and keywords provided at the beginning of each excerpt have been selected by the author to guide the readers and the subsequently provided interpretations. The texts are in English. The version in Italian, original or translated, is proposed in the notes.

[3] In January 1973, the cover of *Casabella* announced the foundation of Global Tools, a cultural experiment organized in the form of workshops, that would last until 1975 and involve a network of actors from Florence, Milan, and Naples. Its main mission was to create a research, teaching, and education program separated from the institutional circle and focused on "the use of natural and artificial material; the development of individual and group activities" as well as the use of "information and communication technology, and survival techniques." Such collective operated in 5 workgroups (Communication, Body, Construction, Survival, and Theory). It was indeed *Casabella* that served as the communication platform for the subjects involved in the Global Tool network. For a full description of the experience, see: Valerio Borgonuovo, Silvia Franceschini, *Global Tools 1973-1975*, Salt, Istanbul 2015.

[4] Silvio Ceccato, an Italian linguist and philosopher. In the early 1950s, he approached the world of cybernetics by contributing to the research of the Scuola Operativa Italiana sulla Modellizzazione dell'attività Mentale e il Rapporto con il Linguaggio (Italian school of modeling of mental activity and the relationship with language). The basis of such research was the identification of three mechanisms: attention, memory, and the correlation between the respective results. Within a decade, he completed three projects: an automatic translator, a prototype of a mental calculator called Adamo II, and a machine able to perceive, classify, and semanticize the surroundings. In the mid-'60s, the research of the cybernetics and language activity center gradually faded, and Ceccato began an intense publication activity. His works include: *Un tecnico fra i filosofi* (2 vols.), Marsilio, Padova 1964 and 1966; *Cibernetica per tutti* (2 vols.), Feltrinelli, Milano 1968 and 1970; *Il maestro inverosimile. Prime esperienze* and *Il maestro inverosimile. Seconde esperienze*, Bompiani, Milano 1971 and 1972; *Il gioco del Teocono*, All'Insegna del Pesce d'Oro, Milano 1971; *La mente vista da un cibernetico*, ERI, Torino 1972.

[5] "Si comunicherà di tutto e dappertutto, con costi decrescenti e velocità crescenti. In tal modo anche civiltà che per millenni avevano proceduto indipendenti si sommano, si incrociano, le tradizioni si sgretolano e la mente ne esce scombussolata.

Massificazione od individualizzazione? Io credo che ne escano rafforzate entrambe, almeno come fatto di scelta, in quanto se tutti potranno ricevere certe informazioni in comune, ognuno potrà scegliendo avvalersi, nella grande ricchezza, di quanto gli sia più congeniale e sviluppare con questo la propria originalità.

Toccherei ora un punto che mi è caro in quanto risponde ad una mia attesa e quindi anche ad un mio consiglio.

L'uomo del futuro farà, o dovrebbe fare, per piacere non poche cose che prima faceva per dovere, ampliando così l'ambito della libertà e restringendo quello della necessità. Lo dobbiamo sia all'automazione sia anch'esso ai nuovi mezzi di comunicazione, la prima che ci sostituisce in certe mansioni, i secondi che ci permettono di non spostarci, partecipando egualmente a ciò che ci interessa. Ne consegue che le attività in cui siamo stati sostituiti saranno ancora eseguite facoltativamente, quanto appunto ci faccia piacere; e già si nota come in questa categoria possa rientrare un saltuario cucinare, fare le spese (shopping), far di cucito, lavare, viaggiare, darsi ad operare di campagna o di giardino, ecc. ecc.

Le operazioni manuali possono restare le stesse, ma diverso è l'atteggiamento nel quale si inquadrano, per esempio, con l'antitesi fra gioco e lavoro, fra economia e gratuità."

[6] Leonardo Mosso studied architecture at the Politecnico di Torino. From 1955 to 1958, he worked at the Alvar Aalto studio of Helsinki. From 1961 to 1986, he was a professor at the Politecnico di Torino. In 1970, he founded together with Laura Castagno the Centro Studi di Cibernetica Ambientale e Architettura Programmata and the Centro Studi Aaltiani of Turin, later renamed Istituto Alvar Aalto.

[7] "In tale quadro alternativo di sviluppo dell'autocoscienza popolare per la formazione di un linguaggio progettuale comune a tutti gli uomini si situano i nostri studi, si situano gli studi di teoria generale della programmazione come autoprogrammazione strutturale del Centro Studi di Cibernetica dell'Univer-

sità di Torino. La programmazione territoriale è quindi un momento particolare del processo di progettazione umana operata direttamente e senza deleghe dagli abitanti di un certo territorio e ciò conseguentemente ad un preciso rifiuto della delega di cultura e di progettazione. Ma gli strumenti dei tale autoprogrammazione, appunto per essere completamente alternativi, possono nascere soltanto dalla rifondazione di tutte le scienze dell'uomo che, partendo da una negazione della propria origine e della propria realtà accademica, nonché della propria confermazione autoritaria e di consulenza alle élite del potere, facciano uscire da sé gli strumenti e le conoscenze che si mettano non solo al servizio di tutti ma che, per loro natura, possano essere utilizzati da tutti ed in primo luogo dai maggiormente sfruttati.
Tale rivoluzione globale, a tutti i livelli della convivenza umana, nella società odierna non è più soltanto un imperativo morale derivante dall'esigenza che tutti gli uomini possano vivere come uguali, è divenuto un imperativo storico e di sopravvivenza indilazionabile. Infatti la logica dello sfruttamento sia elitario dell'uomo sull'uomo sia, ancora elitario seppure con diverse articolazioni, dell'uomo sulla natura, ha portato l'ambiente artificiale dell'uomo in condizioni ultime, le condizioni immediatamente precedenti alla catastrofe ecologica."

[8] Typewritten text stored at the Biblioteca Centrale di Architettura of the Politecnico di Torino.

[9] "In una ipotesi di nuova ecologia e quindi di nuova politica, in cui tutti hanno uguale potere di decisione effettiva, la variabilità e l'orientamento delle leggi probabilistiche dei vincoli, sono determinate dalle scelte comuni.
All'interno di tale legge di probabilità e nel rispetto dei vincoli predeterminati tutte le casistiche di elaborazione quindi le infinite possibilità di scelte singole possono corrispondere perfettamente alle vocazioni individuali, armonicamente inserite nella vocazione comune.
Lo strumento calcolatore appare allora, quando si è gestito popolarmente e democraticamente l'unico strumento in grado di dominare l'enorme complessità delle esigenze individuali e comuni, tenerne memoria e confrontarle nella compatibilità reciproca: quindi essere uno strumento reale di autoprogrammazione."

[10] Gui Bonsiepe studied at the Hochschule für Gestaltung of Ulm, where he later taught at. After the school shut down he emigrated to South America, where he focused his research mainly on interaction and information design. In parallel, he concentrated on the critique of the relationship between the Western world and the "third world," as he defined it in his 1971 text. His major works are included in collections such as *Dall'oggetto all'interfaccia. Mutazioni del design* (original ed. 1993; Italian ed. 1995). His article in *Futuribili* denotes emerging attention to an ecological approach in the design field. The journal was published in November 1967. The Gruppo Futuribili Italia collective branched from the IREA (Institute of applied research and economics), an organization established in Rome in 1963 whose president was Pietro Ferraro, who also became the director of *Futuribili*. In the early 1970s, the journal sparked, in part, the terminology and philosophical debate on the ways of viewing the future more related to the academic world than the political world. Its authors included exponents of Italian design cultures such as Giulio Carlo Argan and Leonardo Benevolo (issue 9-10, 1969 and issue 44, 1972), who took part in the construction of the future as

a moral obligation, as proposed by Ferraro. Design topics are also dealt with in the monographs on "the future of Italian art and natural heritage" (issue 30-31, 1971) and on "the city of humans" (issue 56-57, 1973).

[11] "Alle sei definizioni citate degli obiettivi del disegno industriale dobbiamo infatti aggiungere ancora una tendenza, a partire dalla fine dell'ultimo decennio: mi riferisco al disegno industriale come mezzo per combattere il deterioramento ambientale e per migliorare la qualità di vita del nostro ambiente. A questo punto dovremmo riproporci la domanda se il disegno industriale non sia giunto ad una svolta e si possano conciliare i sei obiettivi ricordati con l'obiettivo di una progettazione ecologicamente impegnata.
[...] In questo sistema il compito principale dell'uomo consisterà nel creare un *feed-back* positivo in opposizione al *feed-back* negativo oggi prevalente.
Ma, per instaurare un rapporto con la natura caratterizzato da *feed-back* positivo, abbiamo bisogno di creare e diffondere una coscienza ecologica.
[...] Quella che noi chiamiamo orgogliosamente "rivoluzione scientifica e tecnologica" si è intromessa nell'ecosistema terrestre senza molto preoccuparsi del futuro e piuttosto avventatamente.
[...] Ogni futurologia che contempli l'istanza tecnocratica è una specie di utopia applicata. Ma l'utopia tecnocratica manca dell'ingrediente più importante tra le componenti del pensiero utopistico: la speranza come forza motivazionale e dinamica nelle speculazioni sul futuro. L'utopia tecnocratica è quindi una utopia senza speranza, un'utopia senza utopia.
[...] Se noi interpretiamo questa affermazione come un invito all'astensione tecnologica, dovremmo dargli questo significato: la nuova tecnologia della società postindustriale dovrebbe essere basata su fondamenti ecologici, essere cioè una tecnologia ecologicamente appropriata, una tecnologia con *feed-back* positivo anziché negativo, come accade oggi."

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# HUMAN BODIES,
# DIGITAL AND VIRTUALITY

# HUMAN IN DIGITAL: MIND AND BODY GRAPPLING WITH PROJECT-MAKING IN A DEMATERIALIZED WORLD[1]

*Flaviano Celaschi*, Francesca Bonetti**, Alberto Calleo*, Giorgio Casoni**

## A problem of jump in species

Hauling human beings into the digital world is a once-in-an-era venture. As Reese (2018) says, after the three previous ages of great transformation (fire and language, agriculture and cities, writing and wheels), humankind must connect actively with the era of today, which he calls the age of "robots and AI". This means, in agreement with Accoto (2019), not only transferring a realistic human image into the virtual space, but also developing a heteromatic and algomatic identity for that specific person, the subject, therefore bringing into the virtual world a complex side of ourselves that we neither yet understand nor dominate.

For us designers, being a party in this process means managing to understand and represent a *model of reality* (that of the subject) which is simple enough to be handled and manipulated and is equally able to reproduce mathematically, so in the only language a machine understands, both the subject and that subject's interpersonal relationships. This very Cartesian method, as we are observing in the field, is to whittle a problem down and imagine it as a series of inter-related layers, one above the other, where each layer can be reproduced, one by one, in the digital environment until their sum gives back a complexity very similar to how it is in reality.

This process is epitomized by *digital (or legal) identities* in Italy, recognized by the country's social, political and economic system as the set of data that confirm a person as a bone fide citizen (fiscal code, back account number, national health number, anthropometric data, personal details, marital status), in other words the full dataset that certifies that a person exists in public life. This is one of the most complex layers in the multi-layer model we were talking about.[2]

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The second layer is the visual and auditory representation of our *synesthetic morphological identity*; it is the shape of our body, especially our face, and the sound of our voice. A relevant study case is presented later. As a further point about this layer, because of the mind-blowing financial investment made by the film and entertainment industry in audio and visual effects, we can now copy human features extremely accurately (impossible to tell apart by naked eye, or so they say), but not everything: our smell is missing, and we do not know how to transmit taste at a distance.

Another layer, also to be explored later, consists in whatever we find it possible to distil through neuroscientific techniques and the applications deriving from these as of today. We could call this *brain identity*. The parametric model that emerges at this layer puts into order and attempts to translate our operational features, the way we work as regards our brain, biology, health and emotions. The effects are amazing in the real dimension, and a progressively more substantial part of these effects, once they have been absorbed by approximation algorithms, can be transferred with relative ease into the digital dimension through small, low-cost devices, as explained by Giorgio Casoni in the next section.

A further layer that is soaking up towering piles of money is the *immersive environment*, the artificial and natural landscape in which we are immersed. Here in Bologna, in Italy, we are installing Leonardo, one of the seven most powerful supercomputers today in the world. Leonardo will have the eminent job to reproduce and model low altitude climate, to build forecasting models. This major investment will also help in giving the artificial environment the sort of realistic features we can perceive, like temperature, light, humidity, windiness and so on, adding them to the artificial sublayer (what we call smart city) which reproduces mathematically and somewhat easily what the atom is in the artificial world, translating it into bits. This is a highly advanced layer, because people, for some time and through two generations of video games, have become used to immersing themselves in simplified, albeit perceptively immersive, realities.

We will start by bringing these layers together and stacking them on top of each other, but the reality that comes out will probably be rather unconvincing. However, this rather sketchy approximation of immersive parallel realities does enable us to develop actions that are recorded and stored instant by instant, bit by bit, thousandth of second by thousandth of second, fragment of image by fragment of image, and all these elements can be associated to us as our general identity. In other words, despite the so far only passable satisfaction, we are in a new world, and all our actions (and thoughts) are transparent and can be turned into data, and so into value, as Zuboff (2019) explained with the term Surveillance Capitalism.[3]

The following analysis is intended to frame the studies presented by other authors at the HBI Symposium, with their vertical explorations into the modes, processes and technologies that enable us to interact with ourselves, with other people and with machines. Our main point concerning the literature we are referring to and the two study cases we will describe, is to open promising doors for contemporary designers taking on the enormous responsibility and sensitivity of handling this jump in species. In other words, we are referring to the help we can give to the *potential to transform individuals* (Pine, Gilmore 1999) in this critical super-adaptation process.

## From virtual reality to metaverse: state-of-the-art in design-driven literature

When, in 1992, Neil Stevenson first came up with the term metaverse, (Stephenson, 1992), the first World Wide Web page had only been published one year earlier in the CERN laboratories by Tim Berners-Lee. Stevenson's description of a digital three-dimensional world, where humans in the form of avatars interacted between themselves and with intelligent software agents, was still the stuff of science fiction. However, from the 2000s onwards, the term metaverse started to be seen in scientific literature (Park & Kim, 2022), which described and analysed its progress (Dionisio et al., 2013), relational models, economic dynamics (Papagiannidis et al., 2008) and technologies.

The first examples of virtual modes go back to the late 1970s and were based on a text-based interface that enabled users located apart to interact in a game environment. As a result of technological advancement, increased computing power of consumer devices and the diffusion of internet access, virtual worlds have evolved into today's interactive three-dimensional environments (Dionisio et al., 2013). Social computing, with the proliferation of social networks and the rising popularity of user-generated content, plus the growth of the video game industry have contributed to the development of practices and dynamics that are currently part of our virtual worlds (Messinger et al., 2009). The next stage in the evolution of virtual worlds is to create an interconnected and enduring network, the metaverse, that allows users to move seamlessly between one virtual world and the next, while retaining realism (immersivity), ubiquity of access, interoperability and scalability (Dionisio et al., 2013).

The pervasiveness of the information dimension and the sensation of presence, given by the perceptual illusion of non-mediation (Lombard & Ditton, 1997) on the part of the interface technology, redefine our Newtonian concept of reality, blurring the concepts of offline and online into an *onlife* experience (Floridi, 2014). Tangible space and the constantly evolving digital information space overlie each other in an "*overground agora*" (Zannoni, 2018). Cyber-physical systems (CPS), the seamless integration of computation and physical processes with the help of processor and sensor networks, are the next exponential evolution in information technology (Lee, 2008). The architecture of spaces has been transformed by fourth industrial revolution innovations, where automation, robotics and artificial intelligence enter into direct relationship with human beings (Pillan et al., 2020). We can thus see that metaverse and virtual modes are interacting evermore easily and frequently, and that technologies, such as augmented reality, virtual reality and blockchains, are opening up new possibilities for use and interaction with the intangible dimension of digital reality.

Within virtual worlds, users take the form of avatars to interact with each other and with software agents, as well as with the virtual environment (Davis et al., 2009). Being able to personalize one's avatar can greatly influence the illusion of virtual body ownership (Waltemate et al., 2018). Studies have shown that virtual arts and objects can be perceived as extensions of one's own physical body, opening up new potential applications in the field of virtual training, prosthetics and entertainment (Slater et al., 2008).

The desire to identify with an avatar that represents one's ideal self and to be part of virtual world communities could be an incentive to use virtual services and goods (Kim et al., 2012), accelerating the development of new consumer models and transformative digital economies.

## VR, AR, MR: enabling technologies and applied neuroscience

Today, there is a certain confusion when talking about the virtual world, especially between virtual reality (VR), augmented reality (AR), mixed reality (MR) and extended reality (XR). While most people use AR and VR to describe the various technologies, their full breadth and scope cannot be conveyed through these two terms alone.

The conceptual differences underpinning the various technologies in play can be explained through the *reality-virtuality continuum* (Milgram & Kishino, 1994) – continuum being the keyword here – which contains the entire spectrum of possibilities between the fully physical word or real environment and the fully digital word or virtual environment. In this continuum, the adjoining parts are nearly indistinguishable and the outer points, as we will see later, are apparently very different from each other.

In figure 1, to the extreme left is the real environment, unmodified, as we humans "see" it (perceptively and cognitively); the virtual environment (*virtual reality*, VR) is at the other end of the continuum, and everything that happens here has been generated by a computer. The area located between the real environment and the virtual environment is hybrid reality (*mixed reality*, MR), with varying degrees of overlaying between physical and virtual worlds, where *augmented reality* (AR) can create a composite vision of physical and digital elements (here virtuality plays a lesser role than reality).

According to the report published by the market research company Allied Market Research (Poddar, 2018), the global market of *extended reality* (XR) is developing at an incredible pace. The market value of these technologies will reach $ 5.36 billion by 2024, recording a 71.6% compound annual growth rate (CAGR) between 2018 and 2024.

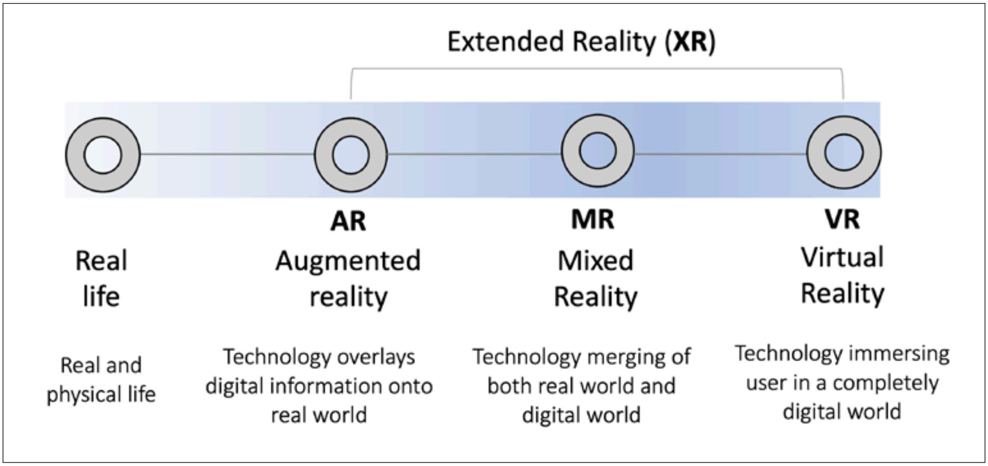
Figure 2 shows a potential segmentation of the technologies that define the VR-AR market; from it, we can see that the XR technology value chain is particularly complex and can be split into many subsets, and that there is a wide array of fields of applications, spanning the sectors of industry, entertainment, marketing and publicity, and healthcare. We should also remember that XR technologies continue to evolve, and we can only guess at their true potential. There is still much to be discovered on how users can interact with these technologies and obtain better results. For readers interested in finding out more, the appendix to this chapter contains a more complete AR-VR taxonomy, together with the most innovative and representative companies that are taking this class of technology to the market.

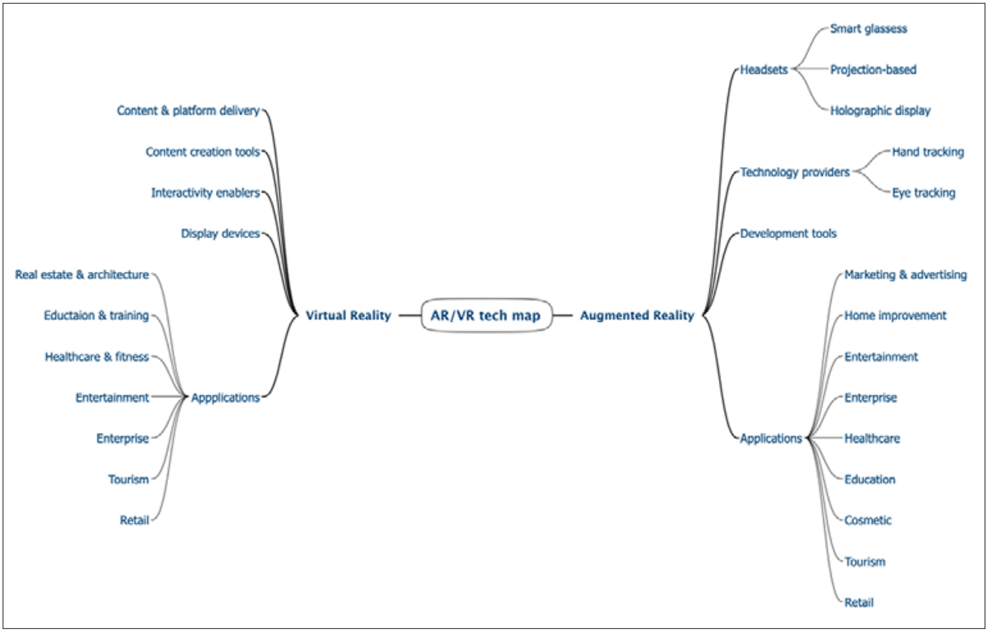
What makes XR technology interesting is the place it is assuming within the fourth industrial revolution (Schwab, 2016), where it is modifying user interfaces, and the next step will be a shift from touch screens to computer-generated images that can be touched and felt through atypical techniques; so, instead of typing with our fingers, we will use our eyes to type much faster on a digital keyboard.

"In previous transformations, it was all about the interface between technology and people; now it becomes all about the experience – and that changes nearly everything." (Scoble & Israel, 2016)

These new forms of XR will be helped in their diffusion and adoption by the expansion of 5G wireless technology, which can provide faster access than any previous generation – up to 3 Gb/s in the real world, depending on the conditions and technology used – and in competition with the speed of optic fibre transmission.

In the debate on XR technology, the focus is often on potential AR, MR and VR applications, overlooking the fact that humans at this point in their journey of evolution are now immersed in processes of "virtualization of reality". We can claim that today's "artificial virtuality" can be placed against humankind's persistent "neuropsychological virtuality of reality".




1. Reality-Virtuality Continuum. Adapted from Milgram and Kishino (1994).

2. Market map for AR and VR technologies.

Neuroscience, in the wake of studies carried out in the latter half of last century, has been able to classify various forms of virtuality generated by the human brain, involving both its perceptive and its cognitive processes.

As Lehman-Wilzig (2021) points out, our perceptive systems will simplify the stimuli that come from reality, both deeply and extensively. In a process he calls "subjective filtration", the senses of sight, hearing and smell tend, for example, to remove a large chunk of information/stimuli from the true reality. Human hearing is restricted to 20 to 20,000 Hz and we are unable to hear infrasound (but an elephant can) or ultrasound (but a bat can). Our vision is based on three primary colours, while insects and birds have receptors that let them distinguish up to six colours (Marshall & Arikawa, 2014). Human smell systems contain 6 million cells, against the 300 million in dogs (Williams, 2011).

When we age, our perceptive systems degenerate, our vision becomes less acute from 40-50 years of age and, from 65 onwards, our senses of smell and taste decay.

The perceptive process (absorb a stimulus) is followed by the cognitive process (assess a stimulus). Even cognitive processes can be virtualized. Think of memory. As Taleb states:

> Memory is more of a self-serving dynamic revision machine: you remember the last time you remembered the event and, without realizing it, change the story at every subsequent remembrance. […] So we pull memories along causative lines, revising them involuntarily and unconsciously. We continuously renarrate past events in the light of what appears to make what we think of as logical sense after these events occur. (Taleb, 2007)

The fundamental thing is to be clear that we are not seeing true reality. We are seeing a story created just for us. Yuval Harari in *Homo Deus* noted that there are two selves in every human being, the "experiencing self" and the "narrating self". The former is our consciousness minute by minute, but lacking memory. The latter instead acts to give meaning to our life, using the clues experienced to draft plausible and coherent stories (Harari, 2015). The value of experience according to experiments conducted by Nobel prize-winner Daniel Kahneman (Fredrickson & Kahneman, 1993; Redelmeier & Kahneman, 1996) is determined by the average between the peaks (positive/negative) and the final results (*peak-end rule*); this is the result reached by the narrating self, who takes a shortcut based on the peak-end rule: the narrating self does not add experiences together, but takes the average.

Examples of our mind's virtualization can be cases of mental illness like schizophrenia, psychosis and delirium, or neurodegenerative diseases like Alzheimer's.

Throughout the course of human evolution, we can discover many episodes of mind virtualization self-induced by taking natural or artificial drugs, or even substances to increase mental performance, such as nootropics.

We can thus state that our perception and cognition of physical reality occurs in a truncated manner and, according to several neuroscientists, "our senses and brain evolved to hide the true nature of reality, not to reveal it… [as] it is too complicated and would take us too much time and energy" (Folger, 2018).

The evidence from neuroscientific research is that the condition of virtuality is a distinctive feature of the human species, where we find ourselves living naturally in our condition of virtualized reality, and are unaware of how far we are being continuously "deceived" by our perception and cognition (Lehman-Wilzig, 2021). The new and ever more present dimension of "artificial virtuality", beyond expanding our concept of reality, could, in the near future, underpin a new transformational awareness about how our cognitive-perceptive systems work in the reality of every day, and how we could activate "debiasing" processes (Soll et al., 2015):

> By not comprehending the essential similarity between "artificial" virtuality (e.g., video games) and – natural - psychological virtuality (distorted perception and cognition) we continue to falsely perceive ourselves as living a mental existence more "naturally real" than it is, and creating an external reality more "unnaturally virtual" than it is. (Lehman-Wilzig, 2021)

## XR technologies for wellbeing

XR technologies, as described above, are a supremely fascinating field of research and application. But what happens within us when we are exposed to these technologies? How does our brain behave when it is "tricked" by a virtual headset? How do our senses react, used as they are to interface only with the world we believe to be real? All these questions outline the close relationship between XR technologies and neuroscience, which tries to capture changes to our nervous system after a given experience. XR and neuroscience can and *must* undergird each other, because an essential part of designing these technologies is to know the properties and limits of our sensory systems. Vice-versa, the brain's responses after an interaction with these technologies can, in turn, give new information on how the brain itself works.

When we come into contact with XR devices, especially when we are first trying them out, we experience a powerful cognitive dissonance. Part of our brain, the more rational and calculating area, is perfectly aware that we are not in any danger. The other part, the more instinctive side, believes instead that the immersive experience is really happening. This is because in virtual reality (or in augmented reality), there is no clear-cut separation between physical world, where our body is, and digital world, in which we are immersed.

This lack of boundaries between physical and digital world is exactly what XR technologies play upon. The fact that we are completely *immersed* and *present* in this new reality makes tasks seem more pleasant, even those we must do, those that are not a game. We can think, for example, of neuro-rehabilitation in patients affected by more or less severe cerebral damage. This rehabilitation generally involves lengthy and continuous treatment and the use of rather unengaging equipment. Several authors claim that part of the improvement gained through XR methods (cognitively, emotionally and physically) is down to the patients' greater motivation to complete their rehabilitation exercises. These exercises are embedded in a real context, making us lead players in the situation we are experiencing. We are literally immersed in the virtual world surrounding us.

XR technologies offer numerous opportunities to speed up and maximize our expected health objectives, in a non-invasive and often highly enjoyable process. As a consequence, we can think of endless applications in healthcare sectors like rehabilitation and psychotherapy (for example, to treat phobias or post-traumatic stress disorder), employing this digital technology to compensate for any lack of equipment or traditional treatment. There is evidence that XR (or more specifically RV) can help in upper limb rehabilitation as part of a patient's treatment for the recovery of motor function (Park et al., 2019; Shin et al., 2016; Standen et al., 2017; Thielbar et al., 2014)Yong-in, Korea, by bringing cognitive aspects into play (Oh et al., 2019; Rogers et al., 2019). These innovative technologies also seem to be beneficial in lower limb rehabilitation, both in helping patients to walk again (Cho et al., 2015) and to improve their balance (In et al., 2016). RV systems have, moreover, been applied successfully in the rehabilitation of patients with multiple sclerosis (Cuesta-Gómez et al., 2020) and Parkinson's disease (Cikajlo & Potisk, 2019).

Outside the medical and rehabilitation sphere, XR can be used in the broader field of wellbeing, to help people keep fit and well and enjoy an active and healthy lifestyle. Several fields of application are described below.

*XR technology helps us keep (or become more) active*

Many of us find it extremely difficult to exercise regularly. Whether we are talking about walking, running or going to the health club, motivation plays a big part. A number of companies, the British Virtually Healthy among them, are studying the positive effects of XR technology on mental and physical health. There are currently various solutions on the market, such as https://www.getsupernatural.com, where they use XR technology to create a fitness revolution and turn workouts into a decisively immersive experience.

*XR technology helps us learn new things*

It is now common knowledge that we are more likely to learn when we interact with the real world, with real people, and when we solve problems in the real situations (Mayer & Alexander, 2017). Sometimes, however, this is not possible, and we can find ourselves having to transmit information sitting on our own in front of a screen. XR technology can offer a tangible solution to this challenge, and several studies have proven its success in helping people learn more about a particular subject (Mills & de Araújo, 1999; Pan et al., 2006; Yang et al., 2010) suggesting that an XR learning environment can simulate a real environment extremely effectively, without a person having to be physically in that real space.

*XR technology lets us connect with others*
When enforced on us, solitude can become loneliness with all its negative mental, psychological and physical consequences. A number of platforms currently on the market use XR to connect us to others, to our family, friends, colleagues or even total strangers. "Social XR" environments (https://halfandhalf.fun/ is a case in point) are platforms where we can meet people in all sorts of virtual places (in the mountains, at the sea, in a park) to talk and share our experiences and spaces, or simply hang out together, making our solitude less heavy.

*XR technology, coupled with sensing technology, helps us feel less anxious*
We all regularly feel anxiety or fear, and sometimes it can be so strong that it blocks us in how we behave. Solutions that combine XR and *biofeedback* sensors can let us know what our anxiety levels are in a given situation, meaning that we can learn to face and control these anxious states. Healium (https://www.tryhealium.com/) is a mental fitness tool that uses *neurofeedback* to improve performance ("powered by your brain"). It uses XR, which can be integrated with *biofeedback* technology, including EEG bands (like the Muse headband) and Apple watches, so the wearers can see their mental state when exposed to a given situation.

We have run through only some of the spheres of application where XR technology can be an extremely powerful tool for improving our wellbeing. Ongoing technological progress is creating an increasingly sophisticated user experience, and the rapidly falling cost of these devices will put them within reach of an ever-growing number of people.

## The digital retail experience case

In the concept film *Hyper-Reality* by Keiichi Matsuda (2016), the main character observes and interacts with her urban environment through the filter of augmented reality. Her field of vision is filled with a constant flow of information, publicity and video calls. Notices, messages, warnings and pop-ups overlay the physical space of the city, where building frontages and supermarket windows and shelves are perceptively augmented by images and sounds. In his depiction, Matsuda imagines a series of problems connected to the extreme use of augmented reality and hyper connectivity, whilst, at the same time, suggesting possible applications in the retail sector.

Today, although in a less excessive way, AR is already being used to offer customers new touchpoints for brands and products. Apple and IKEA, for example, let buyers view items virtually in their own spaces on their smartphones. Ferrero has created an AR *edutainment* app for children. Many brands let customers try on glasses, makeup and shoes *virtually* before buying the items. In the virtual reality world, a number of companies have expressed an interest in investing in projects that use VR to create innovative buying experiences (Alibaba's Buy+, Amazon's VR kiosks). Nevertheless, there are still few real tangible applications and little research so far has gone into exploring the use of VR in retail (Xi & Hamari, 2021).

The online consumer experience is not limited to physical products alone. According to Lehdonvirta, interaction between consumer society (Baudrillard, 1976) and information society (Castells & Himanen, 2002) has led to the *digitalization of consumption*, involving, alongside places, processes and people, even consumer goods themselves (Lehdonvirta, 2012). In this process, the items being bought and sold are no longer physical objects purchased via e-commerce or digital products, such as music and films (information goods), but are virtual products, clothes, accessories and furnishings that exist and can be used only in a virtual world. The reasons why these goods are desirable are the same whether the items are physical, digital or virtual; these reasons are *functional* (the item solves a problem, *hedonistic* (the item brings personal satisfaction in terms of pleasure or excitement) and *social* (the item is the symbol of the buyer belonging to a given social class) (Lehdonvirta & Castronova, 2014).

We have seen that the value associated to virtual goods is closely linked to the attraction of the digital environment for which they were designed (Hamari & Keronen, 2017). The more a virtual world can attract user attention through the content it makes and releases, the more attractive that virtual world is. The unit of measure is not the bit but the experience, and variety of experiences is one of the, obviously, few resources within virtual economies (Lehdonvirta & Castronova, 2014).

As highlighted by Lehdonvirta and Castronova (2014), bringing in users to build content (user-generated content), apart from overcoming the scarcity of original material that development teams can produce on their own, is a way to establish active communities that draw in new users. Furthermore, the fact that users can retain ownership rights over the virtual products they create, meaning that these products can be bought and sold, helps the development of new markets that straddle physical and virtual economies (Papagiannidis et al., 2008). According to Cory Ondrejka (one of the creators of Second Life), if we want to build a metaverse like the one described by Stephenson, we must take a distributed approach to the producing of content, where property rights are taken into account and users can create a virtual economy based on a free market (Ondrejka, 2004). To support this distributed content model, in Second Life, the users have created practically all the assets, all the clothes, vehicles, furnishing items, buildings and potentially any object that can be created using an internal editor (Ondrejka, 2004). Virtual products and services can be exchanged for *Linden dollars* (L$), the currency used in Second Life. Linden dollars can be bought via an exchange using real money (buying and selling Linden dollars) or earned by carrying out virtual jobs. Second Life's economy has evolved over the years into a system with virtual businesses, virtual banks, virtual fund-raising events and virtual private estate management companies (Nazir & Lui, 2016). Additionally, although not allowed by the developers, we are noting that users are excogitating mechanisms to exchange virtual assets for real money (real-money trade) in several *massively multiplayer online role-playing games* (MMORPG), and have moved to specialised websites and platforms like eBay to swap game assets for real money (Ondrejka, 2004).

While, as we have seen, the development and spreading of virtual worlds has generated a new market and new categories of virtual products, it is also the case that, over the years, companies making tangible goods are also setting up virtual spaces in Second Life. Most of these, it must be said, have never been truly offering sales services for their physical products, but are only there for marketing purposes (Bourlakis et al., 2009). Only a few companies like Dell Computers and Reebok offered personalization services and were selling the physical versions of their products. However, a few years after opening, most of these companies stopped being actively present in Second Life (Kuntze et al., 2013).

The explosive growth of the *non-fungible token* (NFT) market out of the blue in 2021 reignited interest in the virtual economy and the metaverse. Blockchain technology means that virtual assets can be identified univocally, and so verify authenticity, provenance and ownership. Non-fungible tokens were first linked to collectibles, videogames and artwork, but they have rapidly extended to clothing, objects d'art, furnishings and virtual lands. Among the most intriguing products are the iridescent dress made by the digital fashion house The Fabricant (https://www.thefabricant.com ) and pieces of furniture from The Shipping by the designer Andrés Reisinger (https://reisinger.studio/the-shipping/).

Despite the large volume of NFT sales, NFTs as a medium for swapping and selling virtual products is so far an unexplored research field, and one that introduces new complexities connected, for example to the technological infrastructure and the extent to which it is difficult to use. However, employing blockchains and NFTs to create a system of relationships between real and virtual economies could play an important part in the development of both metaverse and virtual worlds.

## Conclusions

What we have mentioned has become one of the most exciting fields of study in modern-day advanced design. At the Advanced Design School of Bologna, we study this level of complexity, which we call the "transformative human being"; in other words, the need to design and redesign ourselves continuously and consciously and not just by changing environment into habitat.

Mind and brain, body and limbs, senses and behavior together form the neoplastic substance that we are attracted to, convinced as we are that human beings are antiquated and far behind the experiences they immerse themselves in, deploying technology they themselves created. We believe that the field of observation encompasses the expansion of the self and not the contraction of the reality in which we move. The relationship between subject and enabling technologies, as those described, does not compress experience, but amplifies it, enriches it, so that we can understand ourselves better, as individuals and in our relationship with others and with our surroundings.

Creative designers shoulder a tremendous responsibility. Theirs is the responsibility of delving into knowledge flowing from disciplines where they move clumsily, with the designer's traditional shallowness, dictated by the compelling need to reduce complexity in the model of reality which they are able to manipulate. Meantime, we can use these technologies to build more sophisticated models bursting with stimulations that can be the life-blood of design. Lastly, as the cases on retail and wellbeing would seem to highlight, the most fertile field of study is apparently the one where, embedding ourselves into virtualized models of reality, we have the guts and rashness to keep the hatchways open, so that the interior can interact with the exterior.

Table 1. Appendix AR and VR technologies taxonomy.

| **Technology taxonomy** | **Description** | **Notable companies** |
|---|---|---|
| **AR TECHNOLOGIES** | | |
| Display devices | Manufacturing display devices to view AR content | |
| Headsets | Headsets to display AR content as well as AR display components | Microsoft Hololens, Vajo, Meta, Leapsy, Lynx |
| Smart glasses | Wearable glasses which can be worn over eyes to display AR content as well as AR display components | Magic Leap, Realwear, Vuzix, WaveOptics, nreal, |
| Projection-based | Display devices which enable AR content to be projected and heads-up displays that present data without the need of wearables e.g. for automotive and bikes | Creal, Looking Glass Factory, Avegant, Recon Instruments, VividQ |
| Holographic display | Displays which utilize light diffraction to create a virtual 3D image of an object | Looking Glass Factory VividQ Light Field Lab, Realview Imaging, HYPERVSN |
| Technology providers | Technologies for interaction with AR content through gestures and trackings | |
| Hand tracking | Software tools for enabling AR interaction through detection of hand gestures | uSens, Ultraleap, Crunchfish, 3DiV, Gestigon |
| Eye tracking | Developing methods of AR interaction through eye gestures tracking | Eyefluence, AdHawk Microsystems, 7invensun, BrainVu, Fixational |
| Development tools | Tools for AR development like for instance engines to understand the environment, and AR content creation tools | Blippar, Sketchfab, Camera IQ, Blue Vision Labs, 8th Wall, MAXST |

| Technology taxonomy | Description | Notable companies |
|---|---|---|
| **AR TECHNOLOGIES** | | |
| Applications | AR technology used in different sectors for both consumer and enterprise application | |
| Retail | AR technology for instance for product visualization and virtual trials | Scandit, Perfect Corp, Ditto, Avataar.me, Scapic |
| Cosmetic | AR solutions for beauty products such as makeup, haircare, skin etc. | ModiFace, revieve.com, GlamST, Giaran. Algoface |
| Home improvement | AR solutions for viewing home improvement products like furniture | DigitalBridge, Outward, Cylindo, 3vjia, Threedy.ai |
| Education | AR-based tools for education and learning | Osmo, PlayShifu, Merge, 3DBear, Practically |
| Healthcare | Augmented reality applications for healthcare purposes, such as assistance to doctors | Virti, SentiAR, Proximie, Cognixion |
| Travel and tourism | Solutions for travel and tourism based on AR | GeoVector, Kalpnik, OnSpotStory, eTips |
| Entertainment | AR products focused on entertainment | JetSynthesys, Play Impossible,<br>Terra Virtua, Launchpad Toys |
| Enterprise | AR-based industrial solutions to monitor equipment and machines, and provide maintenance | CompanyCam, Sightcall, Atheer, Upskill, Upskill |
| Marketing and advertising | AR-based solutions to enterprises for advertising and marketing e.g. tech that enable AR-based campaigns, brochures, etc. | Aberdeen, NexTech AR Solutions, Arilyn, Poplar Studio, AdInMo |

## Notes

[1] This paper has been prepared entirely by the authors, and it sets out the results of research conducted at ADU during the international HBI Symposium. However, Flaviano Celaschi was specifically responsible for Sections 1 and 6, Alberto Calleo for Sections 2 and 5, Giorgio Casoni for Section 3 and the Appendixes, and Francesca Bonetti for Section 4.

[2] On this layer, our uniqueness is represented by an alphanumeric code and, as aggression from the outside advances, it contrives One Time Password (OTP) codes and, by generating new passwords, rises new alphanumeric barriers, rolling out a sort of never-ending digital genome, which may be infinite, but can always be overcome as human distractions are also infinite.

[3] I'm not observing you minutely because I like you or you interest me, but because you are source of information that can potentially be industrially transformed into data, and so into value. To give a parallel with the environment, we can say that I am not digging in the earth or in the tropospheric sky to discover the truth, but to produce raw materials that can be bought and sold.

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# VIRTUAL DANCE FOR REAL PEOPLE. DANCING BODY AND DIGITAL TECHNOLOGIES: PRESENCE OR ABSENCE OF BODIES?

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The human body has boundaries, it has an outline, a horizon within which it enters into a relationship with itself, with space-time, and with other bodies.

As the body moves through space, it leaves a trace, and a footprint and can move in multiple ways and nuances with infinite combinations in relation to its environment, to objects, and other bodies.

The contact, which embraces all the senses and can be with hands, feet, hips, eyes, ears, and of different intensities, leaves an imprint that somehow remains inside and outside the body even if the other element, body or object, has moved away.

In the context of performance art, this *memory of the body* is characteristic both of the dancer performing choreography and of the audience enjoying it.

By exploiting this *cognitive memory*, can technology offer new frontiers in the search for movement and the perception of that movement of both a dancing body and a watching body? Or is this memory also affected, risking being obliterated because, due to the many different stimuli that technologies produce, it cannot be deposited? (Suquet, 2011)

The body is an expressive, cognitive, and symbolic medium in the sphere of artistic creativity, a characteristic of the human being.

The dancing *corporeality* understood as an organic and cultural reality is made of flesh and bones, history, codes, personal and inter-human psychophysical techniques, of a sentient and at the same time intellectual knowledge specific to the dancing subjects; it is a traditional, ancient reality, anthropologically founded on the individual and social need to dance, that does not necessarily have to resist and oppose the encounter with the technologies of the 21st century (Di Bernardi & Monda, 2018, p. 7).

A conviction shared by many today, as in the past, is that the digitization of dance must start from the experience of the dancing body and must relate to this.

The experimentations started by individual choreographers, some of them of clear fame, in the previous decades are intensifying within dance companies as real new productions, influencing the choreographic performance action. On the other hand, still, a strong component of the sector is reluctant to use or even to imagine the use of new digital technologies because on the contrary they are convinced that they take away the centrality of the dancing body, perhaps fearing a sort of metaphorical absence or replacement since it is a complex and new dialogue.

On the other hand, how can one blame them? In dance, the body is the main *material*, and this is at the heart of the technological contradictions in several respects. There is in fact a sort of sensory delegation to technology, which places numerous mediators of experience between the body and the world, as well as creating new perceptive experiences. All this leads to a sense of disorientation, of individualism, of modification of the body itself, which becomes *other* from itself.

The absence of the body implies, however, its presence concerning the interaction with digital technology, which allows the expansion or reduction of the perceptual and bodily boundaries and of the possibilities of movement. As some dance historians have pointed out, analyzing contemporary dance in its complexity, it is not so far removed from technology. Together they have gone in search of overcoming the physical boundaries of the human being.

Dance outside of the dancing body seemed an unthinkable concept until the disruptive intervention of Cunningham in the 90s, perhaps not even something to aspire to, if we exclude some of Futurism's experiences. All the forms of extraction of the movement from the dancing body, and first of all the choreographic notation, have always been conceived as instruments to help the dance master and then the choreographer-dancer to fix the movements, to memorize them, therefore deprived of their expressive, artistic autonomy.[1]

1. MicroDanza Meridiana, Fondazione Nazionale della Danza / Aterballetto. Choreography: Diego Tortelli. Danzatrici: Casia Vengoechea, Annemieke Mooji. Photo: Celeste Lombardi. Technological development and user experience design: RE:Lab.

However, choreographers have responded promptly to technological developments, with which they have a kind of double and opposite relationship, of resistance or exaltation.

Merce Cunningham, in *Computer and Dance* (Merce Cunningham Dance Company, 2005), a video interview recorded immediately after the creation of Biped (1999), pointed out that in the second half of the 20th-century dance and new technologies met on the common ground of the creation and perception of images. Cunningham noted that "technology is 90% visual" and, referring to Biped, a performance that can be defined as a manifesto of digital dance, he added: "You see the technology there and at the same time you see the dance."[2] Consequently, his dancers found themselves dancing on stage together with their technological bodies, sort of digital doubles, as Copeland writes, "'liberated' from the performer's body" (Copeland, 2004, p. 192). This idea of detachment, the possibility of dancing outside of the dancers, without them or rather next to them, dancers who had provided, through the technique of Motion Capture, a synthetic scheme of their movement, offered Cunningham the cue to reiterate in the same venue a concept that was fundamental to him: distance from the self increases the knowledge and experience that the dancer has of the action. Cunningham was therefore already aware of how technologies can enrich the process of choreographic creation.

And after him, many have followed this path, bringing new technologies and new ideas for reflection and research into contemporary dance.

In Italy, thanks to the experimental and multimedia dance of Ariella Vidach,[3] in over twenty years of activity, the use of interactive media has been explored in a crescendo of complexity: from the use of video projections on stage that draw on the body, to almost invisible sensors worn by the performers, passing through motion capture and computer graphics. The relationship between body, choreography, and interactive systems has thus become thinner and thinner, and the interference between art and technology has become increasingly refined and suggestive, almost leading to the paradox of dance without dancers, through an animation of metaphysical puppets or avatars of virtual bodies.

Even through William Forsythe's research after 2010 in the Motion Bank project, other possible incarnations of choreography seem to be realized, materializing outside not only the body of the dancers but also outside the physical space of the stage, both the metaphorical one of the theatre and the factual one, tending towards the zero degrees of the performance, that is, constituted by exclusively digital choreographic objects capable of existing in another durable and intelligible state (Monda, 2016, p. 12).

This other reality is revealed in an even more evident and disruptive way through the very recent dance experiments in the *Metaverse* (MCCS Goldsmiths, 2021)[4] in which we witness an interaction between physical forms that are distant in the tangible spatial dimension but reunited in the same instant in a three-dimensional reality reconstructed *ex novo*. An evocative and at times psychedelic experience for the spectator, perhaps a dissociating experience for the performer who, seeing himself literally doubled and without the tangible presence of his dialoguer, must make a greater cognitive and executive effort, as well as having to wear motion capture suits and sensors that hinder freedom and speed of movement.

After all, the body has a weight, and a volume, and if we think of Laban's work based on improvisation, where automatisms and acquired knowledge emerge, it's evident the development of a state of presence-absence that makes the body-mind permeable to the thin sensorineural flows, where the whole human being reacts at the moment.

In the Metaverse, on the other hand, can the intimate interaction of bodies still be defined as such? The dancers are distant, the *contact* takes place within a computer-generated landscape, with their avatars spinning artificially programmed shapes, lights, and particles that intertwine to give a feeling of virtual touch and embodied connection.

Dance is constantly on the move and is looking for unusual, unconventional locations for its tradition. From theatre to cinema, from a platform to a video, from virtual reality to the metaverse, the transition is increasingly quick.

The dialogue does not only take place between dancing bodies, but between dancing bodies and the bodies of the

2. MicroDanza Meridiana, Fondazione Nazionale della Danza / Aterballetto. Choreography: Diego Tortelli. Danzatrici: Casia Vengoechea, Annemieke Mooji. Photo: Celeste Lombardi. Technological development and user experience design: RE:Lab.

spectators. The spectator is *with* and *in* his body (actually, body-mind, body-memory) that experiences the performance, that is, he perceives it, lives it, understands it, and reacts to it. The idea of a presence, that is an artistic and communicative relationship between the performer and the spectator, is thus emerging: a complex dynamic level is constituted, a dramaturgy based on personal dialogue with the person enjoying the performance (Zardi, 2018).

The interest in this relationship between user/spectator and performative action has now become a field of interdisciplinary research and comparison. Scientific studies have been emerging that, in an attempt to investigate the performative process in its entirety, are adopting a multi-disciplinary approach that feeds the dialogue between humanities, performance science, and neuroscience.

Exemplary in this context is the case of two academic researchers, with a background as dancers, who have analyzed and investigated in multiple ways the response of the human body.

Corinne Jola, a researcher in the field of cognitive neuroscience applied to dance, asking the question "what enhances the sense of aesthetic (kinesthetic) movement in the spectator", not only highlighted the basic element of the auditory stimulus such as music and breath, but also the type of movement perceived, vertical and horizontal, and how multisensory areas of the brain are synchronized between spectators when they watch an unusual dance performance. This research is a progression of practice-informed experimental and qualitative studies, often combined in a multi-method, interdisciplinary approach, that she calls "Embodied Neuroscience". Overall, her research aims to better understand the processes of motor learning, movement perception, and ultimately social interaction (Jola, s.d.).

On the other side Bertha Bermudez, choreographer, and dancer, in the project called Paradiso (Ziegler & Las Negras Productions, 2013)[5] has created both an art installation and a research ground for the relationship with the spectator. Paradiso is made up of a series of interactive installations, which expand the cinematic experience of a dance film into physicality, on a double level: *senses* and *spaces*. The movement paths of the hidden dancer and the camera are linked to the position and perception of the spectators. In the first level *senses* the spectator, lying on a comfortable armchair, is *touched* by the movement of the dancer through sensors that give tactile feedback. Images, sounds, the movement of air, and the evaporation of scents activate almost all the senses: sight, hearing, touch, and smell. The spectator's kinesphere is connected to the film camera in the second level *spaces*. Watching the dancer's movements in the film leads the viewer into the movement of the camera's viewing angle, generating an interactive physical montage.

Bertha Bermudez's game about sense perception thereby leads to further reflection.

The lack of even one of these, sight, in particular, causes the perception of a bodily distortion or absence. Dance resides in the audience's sense of sight, although dance itself is a strongly tactile experience. Can we then see dance in other ways?

In this way then, technology, haptics, in particular, can come to the aid of an inclusive experience and support the communicative relationship between performer and blind spectator, thus making the dancer's body present to the touch. A bodily *volume* is created, as the body occupies space, and the air around it is reinterpreted by technology. The Coreo-Haptics project shows that this is possible (Lycouris et al., 2012). This project explores how blind dance audience members can use their hands to experience the dynamic qualities of live dance performances through their sense of touch. The technological arrangement used in this project is as follows: blind users place their palms and fingers on a pad and receive vibrations that aim to make them feel aspects of the movement, such as softness or circular patterns, while dancers perform live (Lycouris & Timmons, 2013).

Therefore, the interaction between bodies, conveyed by technology, becomes intimate because haptic feedback let the audience feel the dance they cannot see.

On the other hand, this *feeling* of the full sensory range, the interaction between real and tangible bodies, has been challenged by the forced isolation of lockdown. The impossibility of touching each other, distance or physical proximity, has brought out new needs and at the same time new challenges related to a renewed awareness of the human body. *Virtual dance for real people* (2021), a project by Fondazione Nazionale della Danza/Aterballetto, best represents, already in its title, a response to the sudden condition in which the whole of humanity has found itself catapulted from one day to the next.

The lockdown and the forced interruption of live performance activities have imposed, in fact, the search for new channels of fruition and accelerated the process of rapprochement between two worlds: the performing arts and the video-digital world. In this way, the entertainment sector has found itself having to face problems that are at the basis of the possible but not automatic relationship between two potentially complementary and allied worlds. The challenge has been to guarantee digital fruition of the show capable of giving back an experience that, for emotions and involvement, could be comparable to the live show.

New scenic forms, therefore, are conceived for fruition that puts the spectator in the condition of reappropriating emotions that are different but no less intense than those of the live experience.

The choice of Fondazione Nazionale della Danza/Aterballetto, through *Virtual dance for real people*, was to explore the relationship between stage creation and virtual reality. This led to the creation of a research project aimed at building a new choreographic study able to offer the spectator a new experience and to put the choreographers in front of original authorial choices - such as creating the work considering a priori the virtual presence of the spectator inside the scene - overturning perspectives and points of view.

The project has provided for the production of dance performances, conceived for virtual reality, of short duration, danced by one or more dancers, and signed by talented choreographers, to be later presented to the audience through a visor. The audience can be welcomed within the same sets in which they were made or in other unprecedented contexts. In this way, the classic "hic et nunc" of the live performance remains the hic, the dedicated place, but a new model of performance is born, visible for weeks at a time in different cities, within locations for which the performances are created, filmed and presented to the public without limits of time and space.

The result was two performances, filmed with Cinematic VR technology, in which the spectator, through a visor, physically and virtually enters the scene and the canonical relationship between public and work is overturned.

The third experimentation, entitled *Meridiana*, signed by Diego Tortelli and supported by Ago/Fabbriche Culturali Modena, added a further step: designing and creating site-specifically inside the spaces of the Historical Pharmacy of the Sant'Agostino complex, it showed a further potentiality by enhancing a historical place thanks to an ad-hoc creation and leaving a multimedia product available for subsequent immersive fruitions (AGO, s.d.).

*Virtual dance for real people* is therefore a project that involves technological and choreographic research capable of accompanying the spectator towards hybrid fruition: neither remotely from home, nor in the theater in contact with the performer, in which dance is presented digitally but not in the abstract.

The transposition into the virtual reality of the spectator's fruition has not only been a powerful response to the pandemic, which has effectively stopped production and closed theaters, but it is also an investment in a type of audience development usually beyond the reach of live performance and outside the main missions pursued today. Technological research should be a partner of the creative process, as well as an exponential amplification of the live performance, and not as its depotentiation, represented, we believe, by the projection of the shows on streaming platforms without video productions that allow adequate fruition to the television medium.

Therefore, with *Virtual dance for real people* FND/Aterballetto started technological research-oriented to connect with new audiences, younger and generally far from theaters, promoting the connection with an *exhibition* concept, which allows a dialogue with the art world, in Italy and Europe.

In conclusion, some further questions arise. Can technological wearable objects, such as visors and haptic gloves, be considered *empathic screens or empathic filters* that provide an immersive experience on equal terms with the live one, through new and unprecedented perceptive-cognitive nuances? Or do they sacrifice the artistic work of the choreographer and the performance, distorting and at times even annihilating both the body of the dancer and the body of the spectator?

Does the body become an absence in the virtual technological world or is it materialized to become an *other presence*? Present and absent in unison, the digital and digitalized body seems to have become a sort of *hyper-body* connotated, if we think in an extreme way of the avatars in the metaverse, in another space and time, where perhaps man has the possibility of realizing "and exteriorizing – taking up Marinetti – his will so that it extends outside of him like an immense invisible arm [...] in which Dream and Desire [...] will reign supreme over tamed Space and Time." (Marinetti, 1910)

We are witnessing the birth of new paradigms, not only thanks to artistic creativity capable of producing new reflections and ideas by exploiting the range of technological proposals available today, but also thanks to technology which, stimulated and driven by new creative needs, can find new solutions.

Within this interdisciplinary scientific dialogue, the human body remains at the center, in an image of Renaissance memory, enhanced in its physical and perceptive possibilities, in a dualism between virtual and real, which finds results in the possibility of an incalculable number of transformations, and perhaps of *reawakening those wings that sleep in the flesh of man*.[6]

**Notes**

[1] *Ibidem*.
[2] *Ibidem*.
[3] https://www.aiep.org/.
[4] It is the registration of the performance *Dancing into the Metaverse: a real-time virtual dance experience*, realised live on November 12, 2021. See also for further insights the latest projects of Swiss choreographer Gilles Jobin entitled *Cosmogony* and *La Comédie virtuelle*: https://www.gillesjobin.com/creations/pieces/.
[5] Paradiso is the last phase of the film project film trilogy *Imagined Dante* by Las Negras Productions, *Imagined Hell, Imagined Purgatory and Imagined Paradiso*. This project is inspired by choreographers Emio Greco and Pieter C. Scholten and their Dante's trilogy, Inferno, Purgatorio and you Para | Diso.
[6] F.T. Marinetti, *ibidem*. "Noi crediamo alla possibilità di un numero incalcolabile di trasformazioni umane, e dichiariamo senza sorridere che nella carne dell'uomo dormono delle ali."

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# EMOTIONS AS A DRIVING FORCE FOR THE DESIGN OF FUTURE PRODUCTS AND SERVICES

*Maura Mengoni*, Silvia Ceccacci**, Luca Giraldi***, Roberto Montanari*****

## Introduction

Nowadays, offering quality products and the corresponding high-quality user experiences is, while necessary, not enough to ensure success in the marketplace (van de Sand et al., 2020).

To maintain their competitiveness, companies must strive to offer their customers a satisfactory CX. This requires that they place their products and/or services at the center of a well-designed and comprehensive customer eXperience (CX) strategy, matched by a communication strategy able to constantly augment all signals conveyed by such products and services.

For this reason, many Western companies continue to shift from providing discrete products to providing and orchestrating a range of services related to one or more products. Designers have therefore shifted their contribution *upstream* to help shape companies' business models and to work on every touch point where people and the company meet (no matter whether this includes additional products, specific services, or both).

When these *interactions* occur, clients may have different levels of reaction, from those that are purely instinctive to those that require the activation of deeper, more analytical processes that also involve their cognitive apparatus. Don Norman identified three different levels of emotional reaction that capture how people emotionally connect to products or services (2004). The first one is called *visceral,* and it states our first impression, where most of us decide if the attitude towards a product or service is positive or critical. The others (*behavioral* and *reflective*) take place once the relationship is established and they address the operational interaction with the product/service (behavioral), or, at a later stage, the wider spectrum of cultural considerations (reflective). Daniel Kahneman identified two parts of our brain (systems 1 and 2) that intervene during any interac-

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tion experience (Morewedge & Kahneman, 2010). System 1 (fast) results in immediate awareness in people, leading them to quickly make a series of decisions regarding the product and/or service, mainly on an emotional and intuitive basis. System 2 (slow) comes later and makes every decision more analytical, rational, data-driven, and sometimes inconsistent with the first (see the so-called "creative paradox" in Rizzo, 2020).

There is a broad agreement among researchers that the first impression is quick, mostly instinctive and emotional, and that most of our subsequent relationship is based on it. Therefore, because this impression is so important, a detailed understanding of how it takes shape and works is crucial for cognitive and behavioral sciences as well as for the design of any CX elements.

Behavior-based research seems to struggle to understand these kinds of reactions using traditional tools such as interviews and questionnaires. At the same time, measurement poses an important challenge, as understanding the specificity of people through emotional reactions can lead to the creation of a grounded knowledge on which a more informed, people-centered design could take shape, to promote better products, services, systems, and thus better experiences. Once the first contact is established, the CX continues, and cognitive evaluations and emotional reactions are combined at each further stage of this interaction. The entire interaction process combines cognition and emotions. Cognition drives the flow of decisions in experiences, while emotions tend to act as a multiplier or solid obstacle. Some studies on usability and user-centered product design emphasize the strong relationship between functionality, usability, and aesthetics. For example, some interactive products, such as an ATM, have been evaluated as more usable due to their look-and-feel (Ceccacci et al., 2018). In other studies focusing on driver behaviors, negative emotions such as fear could have a critical impact on crucial driving actions and maneuvers affecting, for instance, vehicle speed and controllability (Braun et al., 2019). Therefore, an additional challenge that needs to be addressed is to understand the role of emotions in the interaction between users and products/systems at each touch point. The objective measurement of the emotional state is hence crucial and represents an important topic in computer science. The following chapter discusses the available techniques in detail and introduces the one proposed by the Italian startup EMOJ, which has had the merit of being able to integrate emotional coding into a continuous flow of human analysis and adaptation of the human-system interface along the entire customer journey. After a brief overview of the proposed technological framework, a set of use cases to demonstrate the challenging approach in CX design is presented.

## Literature overview on emotion measurement

Among the current technologies that could take the challenge to promote measurements of feelings, emotions, and behaviors for the designer, camera-based sensors, equipped with machine learning and artificial intelligence algorithms, seem to be the most promising. Today, cameras are everywhere: they have become an integral part of our daily lives. It is possible to find them ubiquitously, for example in the cities, in shopping malls, in private homes, and at least one is always in our pockets: the one (or more) embedded in our smartphone. We are all so accustomed to their presence that we no longer care about them, without being fully aware of the large amount of information that can be extracted from the analysis of videos.

This makes the camera a sensor of choice for collecting consumer experience information in a non-invasive way. In fact, thanks to the information that can be extrapolated from the videos through machine learning, it is now possible to have a huge amount of video-related information. For instance, video images can be processed through proper artificial intelligence algorithms to automatically detect information about a personal profile (e.g., gender and age) and/or behavior (e.g., by analyzing eye-gaze and emotions it can be possible to see if a person is distracted, the action that he/she is performing, etc.).

Several methods have been proposed in literature based on image processing and Convolution Neural Networks (CNN) that allow the determination of user gender and age, as proposed by Generosi et al. (2018) and Ceccacci et al. (2018). Some studies tested methods based on regression and CNN to track eye-gaze by using normal webcams or phone cameras (Generosi et al., 2019; Krafka et al., 2016; Papoutsaki et al., 2016).

By analyzing face images from the video, it is possible to identify people's emotions. Many studies proposed methods to recognize patterns from facial expressions and connect them to emotions. Most of them allow the recognition of Ekman's primary emotions (Ekman, 1970) such as fear, anger, joy, surprise, and so forth. They take in input different kinds of pictures and make predictions according to the trained model. By using multiple cameras, it is also possible to track multiple persons' positions and actions within an environment (Arsic et al., 2008; Hamdoun et al., 2008).

The above literature highlights how the measurement of emotions and behaviors is possible. The technology can now be considered pervasive and capable of identifying the complex human state at each touchpoint as long as a camera is present. A key point becomes the assessment of when and where to use this information and how to introduce it in the process of designing and creating a unique, individualized customer experience.

## The new design approach based on complex human state monitoring

*A continuous flow between analysis and reaction*

The discussion on the current challenges in customer experience has highlighted how strategic it has become to understand customer emotions and behavior mapping during the interaction with every touchpoint along the customer journey. However, if this knowledge is not reported operationally in the construction of an adaptive customer experience, it could be useful only for investigative purposes and for orienting the creative design processes. Therefore, the goal is to exploit data about human monitoring to make services, human-machine interfaces, and all living environments adaptable to human emotions, and in the condition to realize a more satisfying, engaging, and empathetic experience.

The introduction of emotions in a continuous flow of analysis-reaction-feedback requires, on one hand, the availability of an interconnected network of sensors and actuators – that is, the Internet of Things (IoT), distributed in the environment and embedded in products – and, on the other hand. the development of an emotional-sensitive system to responsively adapt to user behavior and profile to generate individualized experiences. In addition, upstream in the design process, the designer must consider the degree of product interactivity ensured by the current extensive penetration of IoT technologies and then provide a certain level of flexibility to make it adaptable to the customer. While the latter aspect relies on the designer's mindset change and expertise in technologies, the first one can be reached by proposing a new design approach enabling the management of customer experience strategies.

This is characterized by a customer-centered iterative perspective and consists of the following steps:

1. *Analysis of customers along their journey:* it implies the observation of customer behaviors and the understanding of their emotional state during the interactions with any elements characterizing the touchpoints (e.g., products, services, advertisements). This requires the presence of a real-time emotional recognition platform able to trace and analyze the customer behavior along the multi-channel journey, and to acquire useful information to predict the level of customer satisfaction (e.g., customer emotions, postures, gestures), in a non-intrusive way. The results of the analysis can be represented through the construction of the customer journey map, which represents the main touchpoints in the store, and the creation of the emotional curve to graphically show the level of customer satisfaction and to recognize which touchpoints need to be redesigned or adapted.
2. *Planning of strategies to improve the customer experience:* definition of all changes to be applied to any touchpoint to enable customer experience personalization. This activity can be supported through big data analysis. Data collected during the analysis stage can be processed to map the customers' behavioral responses to the main features of the touchpoints. In this way, for each customer stereotype, it is possible to determine the configuration that corresponds to the higher level of customer satisfaction. This supports the definition of touchpoint adaptation requirements more objectively and rationally.
3. *Development of all individualized experiences for every critical touchpoint:* this may require the re-design of products and

services affecting each touchpoint, thus the design of new interactive systems, able to adapt their features based on the user interaction experience. To this end, proper adaptation rules can be automatically generated and managed through machine learning algorithms or the data knowledge base previously acquired.

4. *Implementation, testing, and evaluation:* implementation of new products and services and every signals along the customer journey and measurement of customer satisfaction in order to define possible improvements such as varying the order of the stimuli, proposing design guidelines to make the product more pleasant or the journey more attractive, and so on. Results of these activities include the processing of data collected through the construction of the emotional curve and guidelines to improve the CX.

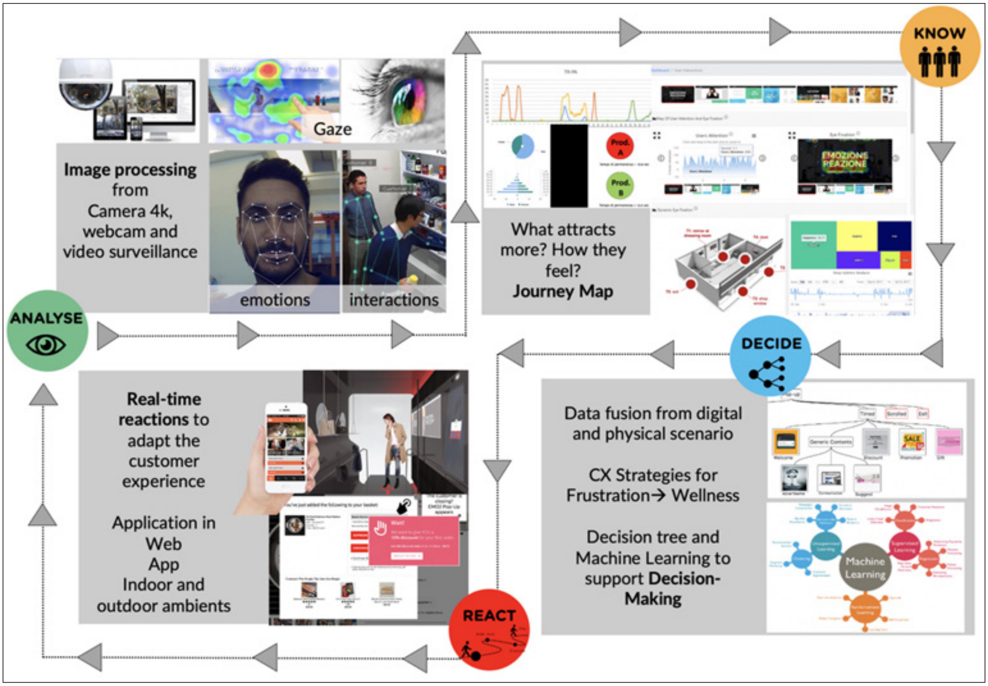
*EMOJ framework*

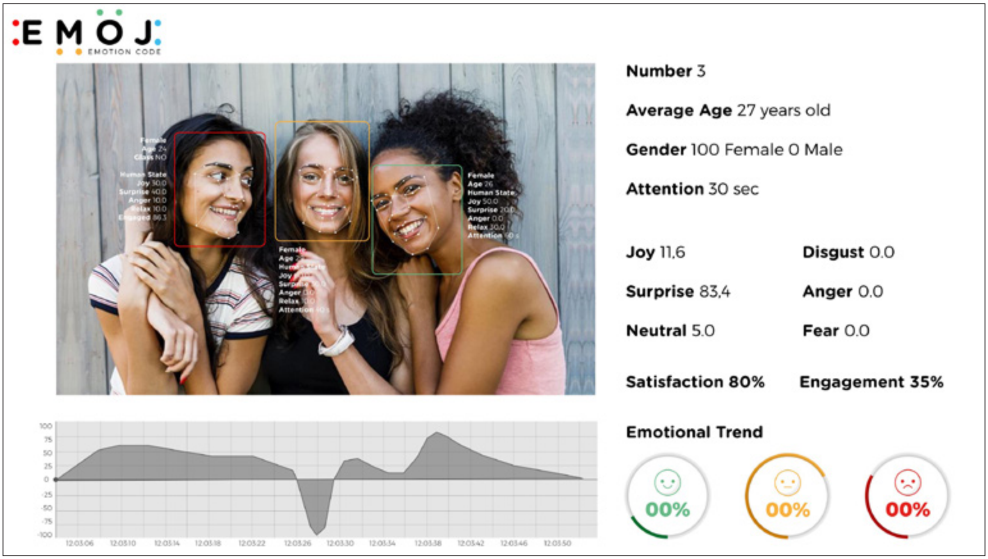
The implementation of the proposed holistic approach contributes to advancing the state-of-the-art both in design and computer science. It requires an interconnected, integral, and flexible technological framework enabling all conceptual steps, from analysis to adaptive reactions, to user feedback, in order to effectively transform the recognized customer feelings from negative to positive, intercept their wishes, and respond in real-time to make them more satisfied.

In 2017, EMOJ was born as a spin-off of the Polytechnic University of Marche, with the aim to provide designers and digital strategists with a technological framework able to realize such an approach. The framework is based on three modules: one to analyze all human-system interactions at every touchpoint, one to acknowledge some important metrics to assess the CX, and one to decide and react in real-time to changes in the human state to realize a pleasant, engaging, and personalized experience.

The first module allows the acquisition of several types of information related to customer behavior. It implements several technologies, such as face recognition, facial expression recognition, eye-gaze tracking, head tracking, and body posture tracking.

The second module provides a collection of smart analytics tools that enable collected data processing quickly and easily, to




1. The technological framework and the emotion recognition module.

extrapolate useful insight to better understand the touchpoint features that most affect the customer experience.

The last module exploits the system described in Ceccacci et al. (2018). It implements artificial intelligence algorithms (machine learning) based on inductive inference, making decisions based on logical rules derived from a knowledge base defined through the relations between customers profiles and the adaptable feature of products/ services/features determined through the analysis of historic data, or according to the results of psychological and marketing studies. In this way, the system can monitor the customers any time they approach any touchpoint along their journey and react by adapting the experience based on their emotions and behavior.

## Case history

The multidisciplinary nature of the approach and the cross-applicability of the technology can be demonstrated by numerous applications of the EMOJ framework, illustrated as follows.

*Audience measurement*

The first application is the system used for audience measurement in the context of live opera shows, in the open-air neoclassical theatre Arena Sferisterio of Macerata.

Infrared cameras were positioned in the Sferisterio arena to detect the audience's facial expressions during the show. The software adopted in this context implements a combination of face recognition and gaze tracking technologies based on artificial intelligence algorithms, as described in detail in Generosi et al. (2020) and Talipu et al. (2019). It enables the age and gender recognition of people shot by the cameras, the monitoring of their emotional state, and their corresponding level of interest and involvement. It provides two indicators that offer a more complete picture of the emotional state of a user: valence and engagement. It also provides an estimate of people's attention based on the angle of rotation of the face, with respect to a point of interest, using the method described in Ceccacci et al. (2020).

Collected data were processed to analyze the dynamics of the audience's emotional behavior during the performances to investigate the level of customer satisfaction reported by spectators. Results highlighted that collected data related to audiences can be useful for the artistic director to estimate the audience's overall level of satisfaction and to better guide the choices regarding the specific characteristics of the performance and casting, to improve the artistic offer.

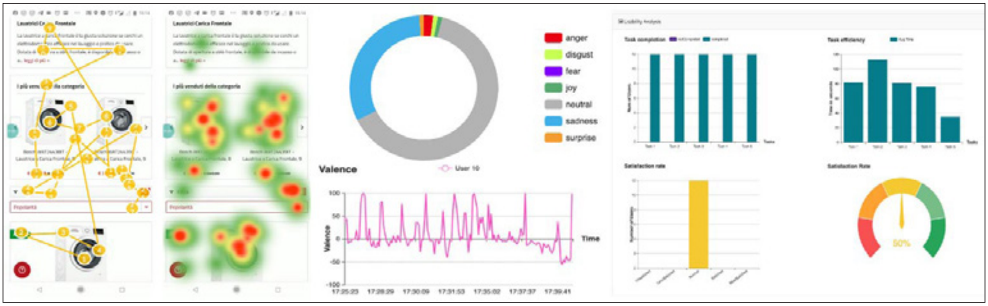
*Remote usability testing*

The technology can also be embedded in mobile apps and websites to monitor the user experience and automatically find usability issues. It tracks user interactions such as scrolls and clicks, plotting gaze and recording heatmaps, assessing the satisfaction rate, and completely mapping the user journey. The aim is to assess user behavior easily, automatically, and in remote mode to improve app usability. The remote usability testing platform is developed based on artificial intelligence. More specifically, a deep learning approach is taken to develop the platform. Computer vision and state-of-the-art image processing techniques are implemented. The platform is able to evaluate the test results automatically and visualizes them on the dashboard, through which it enables the management of participants during the tests. It also tracks participant behavior during the performed task. Multiple graphs and charts addressing different aspects of usability are generated in the different sections of the dashboard. Common analytics only answers *what*, while our UX track can answer *why*.

*A multisensory touchpoint in retail: the Evoque tunnel*

Once the system has recognized the person's age, gender, emotions, and in some cases his/her identity, it is able to adapt the user experience based on his/her state in order to realize a sensible, reactive, and personalized environment. The control of multiple devices is managed by decision-tree algorithms and machine learning.

The application you see in this slide is an emotional tunnel equipped with multiple cameras, LED lighting, LCDs, video projectors, and speakers. When a person enters the tunnel, she/he is recognized and a customized experience is offered. Lights change according to her/his emotions, and a video mapping appears. Every stimulus changes in real-time. The Evoque tunnel





2. Results from the UX track in the case of a mobile e-commerce app.

3. The Evoque tunnel concept.

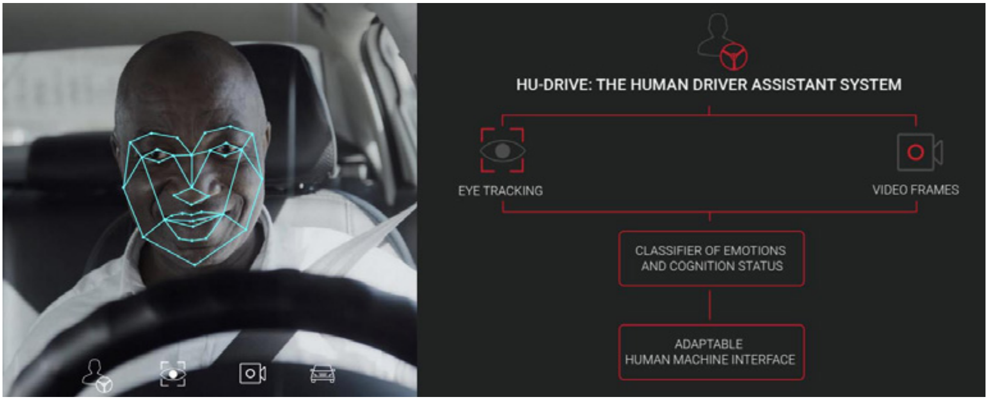
was built and installed at the 2018 Retail Forum in Milan to communicate a popular luxury shoe brand.

*Adaptive multimedia totem for museums*

The second application is a multimedia totem for museums equipped with a webcam on the top. When visitors are in front of it, EMOJ captures their age, gender, and emotions and is associated with a specific museum cluster, such as annoyed visitors, curious visitors, or thoughtful people. Based on the cluster, the system proposes a journey across the museum through the visualization of different artworks. The visitors can visualize the list of the proposed attractions and watch videos providing interesting information about them and their authors. At the end of the digital experience, visitors can download a map of the proposed journey and start the visit. The totem was placed at the entrance of the rooms that host the Modern Art exhibition of Palazzo Buonaccorsi. The application was available to visitors for 2 months, during which the experimentation was carried out. A total of 1976 experiences related to one or more people have been analyzed. Results, reported in Altieri et al. (2021) underline how the Totem has worked to create an interactive and emotional link with the groups, positively influencing their mood in the Pre-Experience phase and the subsequent Post-Experience phase. In particular, they highlight that the proposed system, designed to act as emotional leverage, has been able to improve the positiveness of the emotions experienced by the visitors.

*Adaptive HMI for automotive: Hu-Drive technology*

Many of today's vehicles are equipped with Advanced Driver Assistance Systems (ADAS) that automatically recognize and react to potentially risky events in the driving scenario. A further step towards safety could be taken by addressing what is most human, that is driver's emotions. Intense, overwhelming emotions can impair the driver's judgement and effectiveness. This preamble has guided the development of a concept that EMOJ – in cooperation with RE:Lab (an Italian company focused on Human Machine Interface design) – created and presented at CES 2021. The Hu-Drive is a human driver assistant system that dynamically adapts Human-Machine Interface to the driver's




4. The HU-Drive architecture.

emotional state. The HU-Drive solution consists of two modules: module 1 recognizes the driver's emotional and cognitive state from images that are captured by cameras inside the cockpit and processed by Deep Neural Networks; module 2 is a set of HMI adaptation strategies that are triggered once a specific state is detected, to help the driver manage emotions and act safely. Anytime a critical state is detected, HMI can nudge the drivers to control their emotions and thereby act safely. Preliminary tests of the HU-Drive technology have been published by Ceccacci et al. (2020).

*Advances in distance learning and digital events*

EMOJ takes the opportunity of Covid-19 to study and launch a product line dedicated to distance learning and, after its success, to streamed events. Corsincloud is an e-learning platform to deliver compulsory professional training courses. It implements the system described in Ceccacci et al. (2020), which exploits the most recent developments in Deep Learning and Computer Vision for Affective Computing, in compliance with the European GDPR. When the user starts to watch a video lesson, a tool is launched, accessing the front-facing camera. Taking as input the video captured by the webcam of the device used to attend the course, Corsincloud: (1) performs continuous student authentication based on face recognition; (2) monitors the student's level of attention through head orientation tracking and gaze detection analysis; (3) estimates student's emotions during the course. Moreover, it checks the number of people captured by the camera. When more than one person is found in the image, the check is considered false.

The results of a preliminary survey reported in Ceccacci et al. (2020) suggest that the system is effective and robust. Participants judged the system as easy to use, despite some deemed it too coercive. With similar functionalities, two other solutions have been developed: Esamincloud and Eventincloud. Esamincloud also includes the functions of a *lockdown* browser to check that students are not copying during the online exam. Eventincloud is a live event (meetings, conferences, seminars) monitoring software that measures in real-time the engagement rate, satisfaction, and interaction level of the host user.

## Conclusion

Today's scenario has rapidly changed, driven by the intention to increasingly tailor products, services, and experiences to the customers. However, CX should not only be considered from the perspective of harmonizing the initiatives, actions, and reactions of users and all the touchpoints they encounter while accessing a product, a service, or a combination of both. Conversely, other elements appear to be crucial in activating and maintaining such relationships, among which emotions play a strategic role.

Emotions are fundamental in that they influence our behavior and cognition, our decisions on whether to act or not, or the way we perceive and interpret reality, and they direct and prioritize our attention. Therefore, understanding emotions should be considered not only as a new research perspective introduced with the publication of Rosalind Picard's book on affective computing (1997), but as something that will become a driving force in the design and development of products, services, and generally anything that represents a CX. Emotions drive the first connection with products and services, guiding the decision we make in evaluating whether something is good or bad, and based on this, emotions will guide the next steps in experiences with products and services. Therefore, the role of emotions in design is critical. In this context, technologies should not only be considered as tools to detect the emotional state of users in real-time but also as a means to govern the adaptation of their interaction with each other.

This is exactly the approach followed by EMOJ, a technological framework that detects emotional status, and consequently intervenes to adapt the quality and nature of services in a public event such as an opera, in a museum interaction experience, in the vehicle HMI, or the support for distance learning and assessment.

Initial results achieved through the use cases presented have provided a solid set of empirical data for this technological framework. In the meanwhile, this approach is constituting a new tool for designers and for a design process that – being aware of emotional reaction – could guide the creation of products and services that are even more customer-centric, and finally more empathetic.

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# CULTURE AND CREATIVITY IN INCORPOREAL CITIES. DESIGNING COLLECTIVE CREATIVE BODIES

*Elena Vai**

## **Performative events as design agents for new cultural behaviors**

Cultural and creative sectors are a significant driver of local development through job creation and income generation, spurring innovation across the economy. Beyond their economic impacts, they also have significant social impacts, from supporting health and well-being to promoting social inclusion and local social capital.
OECD, *Culture and the creative economy in Emilia-Romagna, Italy*, 2022

In the visual and performing arts, the body and its representation have always been assumed as a parameter for measuring space, crystallizing presence, and sublimating the body in time.

In design cultures, the body becomes raw material for constructing relationships between cultural-social content and the spaces and objects (material or immaterial) that preserve the trace of this relationship (Norman, 1990).

Today, design, creativity, and cultural and creative industries are listed among the drivers that can drive the contemporary phase of uncertainty and crisis.

The contribution moves from the research question about how much can policies, design processes, cultural and creative practices and events contribute to create responses to the need for continuous adaptation of people in the cities.

With the first but brief experiments in immersive Virtual Reality in the late 1980s and early 1990s (Caronia, 2010) and the irruption of incorporeality, the body-creativity-project-time relationship, previously experienced in a uniquely phenomenological-perceptual and situated dimension, breaks down.

Of this privileged lost physical relationship and the revolutionary emergence of the concept of incorporeality, traces can be found in the prophetic narratives contained in *The City*

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*of Bits. Spaces, Places and Information Highways* (Mitchell, 1997), in which the author investigates the epiphany of "online environments", tracing the genesis of the founding of the "global village" of the twenty-first century. A territory connoted by "electronic agoras" inhabited by antispatial, fragmented, incorporeal identities, whose conversations are asynchronous and participation conditioned by broadband connection, with the possibility of leaving by establishing or severing the connection to the network.

> The purpose is to describe an emerging but still invisible reality, the city of the twenty-first century […] to imagine and create environments, digitally mediated, for the kind of life we want to lead and the kind of community we want to have. (Mitchell, 1997)

The interest in analyzing the role of design in the construction of relationships between bodies and spaces and its generative capacity lies in my personal experience as a practitioner of embodied creativity in the production of events. I have been aware of their value as agents of transformation (Celaschi et al., 2019), anticipatory prototypes of the future (Vai, 2021), spatiality, corporeality, proximity (Formia et al., 2021a), community (Djalali et al., 2019) and digital synchronicity heir to Mitchell's anticipatory scenarios:

> the digital telecommunications revolution, the increasing miniaturization of electronics, the commodification of bits, and the growing dominance of software over material form […] were building an information highway, thus reconfiguring space-time relationships in ways that promised to transform our lives for good. (Mitchell, 1997, p. 6)

I have been interested in this reconfiguration of spatial-temporal relations that bodies are undergoing in an increasingly incorporeal city context, identifying temporary events as the enabling space for experimentation and design of new cultural products, services and behaviors.

In the preface to the American edition of *A Landscape of Events* (2000), Bernard Tschumi illuminates Virilio's analysis of the acceleration of time to the point where space itself is swallowed up by time: "Space becomes temporal. […] Time is what allows us to measure space."

In the past two decades, time has progressively assumed the role of a product that conditions any body-creativity-design-environment relationship. It is in the dimension of time, even more than in physical space, that every relational action is designed and performed.

We live bodies augmented by technological prostheses thanks to increasingly intelligent miniaturized and dematerialized *software*. Paradoxically today our memory, the technologies themselves and the objects that surround us, are subject to rapid obsolescence.

Since the first decade of the 2000s with the emergence of social networks and sharing platforms, encounters, relationships, and the production of cultural products and services have been designed through the mediation of devices that have enabled the migration of many behaviors into the digital dimension.

The poetics of many contemporary artists, the productions of the cultural and creative industries expressed in events can be documents and signals of the restlessness we are experiencing as human beings (body-mind) in the attempt to find a balance between the real world and its digital double.

Already Mitchell mentioned the reduction of many objects to “repertoires of digital archaeology”, introducing the value of digital memory. The issue of preservation, and new fruition of digitalized heritages is increasingly emerging in the areas of creativity and culture, that are considered non-alienable public goods (Unesco, 2022).

Today, the need to record, save, store, in order to preserve, reproduce and share cultural content, some born in the virtual dimension, opens up unprecedented realms of production of new “cultural bodies” and innovative models of their fruition in performative events, designed themselves in hybrid and dual modes.

The question this chapter seeks to answer is whether policies, products and services designed by cultural and creative industries can be relieving solutions to the need for continuous adaptation of bodies in more and more incorporeal cities.

## Bodies as living archives

> The metaphor of the body-archive refers to the idea that the materiality of the body can be understood as a set of documents capable of suggesting meanings beyond the physical dimension and guarding remote and constantly changing knowledge.
> Susanne Franco, *Corpo-archivio: mappatura di una nozione tra incorporazione e pratica coreografica*, 2019

The various theorizations of the body as archive (Franco, 2019) elaborated by researchers, critics and artists are not only fueling new theoretical and practical approaches to the histories of different cultural and creative disciplines, but are helping to broaden the debate in design cultures about Human Body Design, and the emergence of new behaviors.

Innovating the design of "cultural bodies" involves actively engaging those who research, experiment with, and enjoy these products, taking into account their interaction and the dual nature of the environment (real and digital).

In the artistic avant-gardes of the 1960s and 1970s, Viennese Actionism, performance, happenings, and radical design, the body became the subject, object, and practice of actions that engaged physical spaces and viewers in experiments that drew on literary repertoires of myths, rituals, and tragedies.

In the next two decades, in the 1980s and 1990s, the body-action gradually gives way to its representation. There is a progressive thinning of bodily substance, reduced to pure painting (i.e. the Transavanguardia movement), not interacting with the users. In those decades in the field of design, designer-star authorship is expressed through serial iconic forms (one among many, Philippe Starck's Juicy Salif for Alessi) with respect to which a critical-contemplative, rather than tactile and functional, attitude is demanded.

Since the late 1990s, abetted by the digital revolution initiated by CERN's public release of the *World Wide Web* technology in 1993, artists and designers have gradually drawn closer together in the production and distribution models of works and objects.

To the unambiguous definitions of design as a specific discipline pertaining to industrial design, which had marked the literature from the postwar period onward, the conceptual positions of Critical Design emerged in those years, which essentially and progressively elided the functional relationship of the body from the design of the object.

> Indeed, at the same time that practices that used art forms were spreading in design, artistic practices that enacted design forms were multiplying in the contemporary art world. Faced with this double movement, it then becomes legitimate to ask what differentiates these practices, which often focus on the same objects. (Quinz, 2018, p. 15)

The reflection on the "same objects" conducted indiscriminately by designers and artists in collaboration with scientists is investigated in *Art, Technology and Science* (Mancuso, 2018), in which elements of convergence between different disciplines and practices are emphasized, thanks to the diffusion of enabling technologies in all fields of knowledge, in art, design and more generally in the areas of contemporary culture production.

The body becomes a prototype, a field of experimentation, an environment for implants of technological prostheses and wearable devices.

The evaluation that is expressed is that of an artistic panorama in the field of New Media Art changed in its relationship with industrial research (hardware, software and networks) and science, thanks to its own ability to activate systems between different entities:

> In fact, one observes an increasing number of artists, designers, creatives and industries – in ICT and scientific research circuits – involved in the design of sustainable development models for the realization of a cultural and artistic "object." The new creative classes [...] are today able to connect industry with an ecosystem made up of research centers, laboratories, academies, and exhibition spaces such as to activate systems of conception and circulation of a work to which, normally, the company would not have access. (Mancuso, 2018, p. 13)

Therefore, the following reflection aims to explore the role of CCIs and policies in their support, also in light of the impacts due to the pandemic crisis (Lhermitte et al., 2021), in the construction of ecosystems that allow original interactions between culture, creativity, cultural and creative productions.

The aim is to anticipate possible scenarios and processes to protect micro creative realities, to offer them the right of existence, fostering and expanding their metabolism through interaction with international realities.

The hope is to direct actions and tools toward the design of new cultural and creative products and services that influence new cultural and social "bodies". These new "collective creative bodies" could be considered prototypical solutions, based on the return to the centrality of the presence, the need for real encounter and the need to feel part of a large community.

## New collective creative bodies: the role of CCI and policies in designing ecosystems

> Knowledge is no longer a disciplinary corpus, but "is" the environment in which we are immersed. Therefore, the artist is no longer connoted to the role of the revolutionary-genius, but, like the designer, engineer and scientist, he investigates the environment that surrounds us. Art, cinema, theater, music, and design all recover the aspect of their craftsmanship, becoming themselves tools, overcoming disciplinary boundaries and contributing, through new fusion processes, to defining new aesthetics for the future.
>
> Elena Formia, Elena Vai, *La cura del futuro*, 2019

In a book written in the early months of the pandemic, *Design and Mutations. Processes for the Continuous Transformation of the City* (Formia et al., 2021b), I had focused attention toward processes, practices and methodologies deployed by designers and creatives for responsible transformation in the social and cultural care of cities, which had arisen in response to a radically and subtly transformed context.

> Unprecedented practices were devised by designers, planners, curators, and citizens – from the invention of new models of engagement to the reactivation of places, from the creation of original content to unconventional uses of online heritage, from the hybridization of channels for communication to new processes of cultural production and dissemination – that, thanks to digital platforms, were rapidly disseminated, entailing immediate impacts in different spheres. (Vai, 2021)

In this contribution my aim is to explore the role of design and policies supporting CCI as agents of transformation, introducing interaction and the generative capacity of relationships as macro categories. Through this generative perspective I have selected actions, strategies and initiatives related to the context of Emilia-Romagna region, which I believe are potential tools in response to the need of CCI to design unprecedented interacting and immersive relationships between bodies and spaces, open to contamination with international experiences.

The methodology adopted in choosing themes refers to initiatives, projects and policies, related to the Emilia-Romagna region, in which CCI sectors and design assume centrality as agents in designing relationship and people engagement.

The criteria by which strategies and actions are listed follows themes:

- designing relationships through the interaction of physical bodies and physical spaces;
- designing relationships through the interaction of physical bodies and digital spaces;
- designing relationships through the interaction of virtual bodies and physical spaces;
- designing relationships through the interaction of virtual bodies and digital spaces.

*Designing relationships through the interaction of physical bodies and physical spaces: festivals*

Since the founding of the D.A.M.S. program at the University of Bologna in the early 1970s, Bologna became a place of experimentation that attracted and trained generations of creatives in the different disciplines of the Visual and Performing Arts, Music and Cinema.

Over the decades, the city and the territory, not only on a regional scale, have been crossed-fertilized by design practices for the development of cultural and creative products, many of which materialized and distributed thanks to the birth of important festivals.

From 1977 to 1982, the International Performance Weeks attracted famous artists such as Marina Abramović, Vincenzo Agnetti, Renate Bertlmann, Giordano Falzoni, Geoffrey Hendricks and Brian Buczak, Robert Kushner, Hermann Nitsch, and John Cage. Today these "actions of relationship" between *body art actions* and spaces are being enhanced through the public exhibition of the original videos, thanks to the opening of a new permanent section of the MAMbo Museum entitled *Archival Surveys. International Performance Weeks and the 1960s and 1970s in Bologna and Emilia Romagna*.

In the field of theater and dance, Santarcangelo dei Teatri activates a temporary community composed of artists, citizens and the audience who confront each other through events and a schedule of appointments throughout the year, reflecting on the relationship between art and the city. Since 1971, the Festival has become the European benchmark for experimenting with new models of content creation, interaction between people and public space, and unprecedented models of sociality.

In the film industry, unique is the presence of cult filmmakers who have chosen the region's characters and landscapes as locations for the production of their films (Pier Paolo Pasolini, Federico Fellini, Michelangelo Antonioni, Bernardo Bertolucci, Marco Bellocchio, Valerio Zurlini, Pupi Avati, etc.), or as Carlo Di Carlo questions "I don't know to what extent it is a land of filmmakers or a landscape that has suggested to filmmakers to be interpreted." (*The Roots of Dreams*, 2014)

It is highly likely that the movie industry that has developed in the region has contributed to the emergence of more than 50 festivals, many of them with an international scope. See among them the thirty-sixth edition of Il Cinema Ritrovato in Bologna, a unicum in the programming of unreleased and/or restored films by the Fondazione Cineteca di Bologna; the fortieth edition of Bellaria Film Festival, dedicated to independent cinema; the twenty-second edition of Future Film Festival dedicated to animation, visual effects, virtual and augmented reality, gaming and media arts; the eighteenth of the Biografilm Festival, dedicated to biopics.

In the music sector, Node festival in Modena (nominated Creative City Unesco for MediaArts) combines live media performances, audiovisual projects and educational formats to bring young people closer to the new digital arts. These were the same objectives that have driven the design of the Robot Festival in Bologna since 2008.

1. Archive surveys. The International Weeks of Performance and the 1960s and 1970s in Bologna and Emilia Romagna. Exhibition view at MAMbo - Museum of Modern Art of Bologna. Detail: The third International Performance Week. The new dance. Gallery of Modern Art of Bologna, 1-7 June 1979. Photo Ornella De Carlo. Courtesy Settore Musei Civici Bologna.


2. Archive surveys. The International Weeks of Performance and the 1960s and 1970s in Bologna and Emilia Romagna. Exhibition view at MAMbo - Museum of Modern Art of Bologna. Photo Ornella De Carlo. Courtesy Settore Musei Civici Bologna.

In the area of representation, Fotografia Europea Festival in Reggio Emilia has been exhibiting the best of international production in cloisters, churches, galleries and museums since 2007, through exhibitions, meetings and performances, and it has activated synergies with the biennial event FOTO/INDUSTRIA promoted by the MAST Foundation in Bologna since 2015.

In the area of design, the five editions of Bologna Design Week have helped to activate transversal relationships between students, professionals in the different fields of the discipline and CCI. The goal has been to map and bring together the cultural, educational, creative, productive and distributive excellences of the territory in a logic of open innovation and participatory design.

Regarding dance, the National Aterballetto Foundation based in Reggio Emilia, in 2022 proposes the project *Primavera di corpi, luoghi e danza*, a spring to decline new artistic and social horizons, between virtuosity and fragility, between research and technological innovation, between stages and urban spaces where performing choreographies and their fruition with completely new models.

These festivals, which are not exhaustive of the plurality of annual offer, demonstrate the vitality of the CCI sectors, which the pandemic crisis has to some extent limited, but which nonetheless has prompted reflection on new ways of digitally enjoying content, no longer just in presence, thus opening up the creation of new multiplatform formats and new multimedia profiles.

### *Designing relationships through the interaction of physical bodies and digital spaces: online platforms*

Over the past decade, the region has turned its attention toward building reports and online repositories dedicated to mapping the emerging phenomenon of CCI (Celaschi & Vai, 2021).

The performing arts system was observed through the emiliaromagnacreativa.it platform, which collects more than 70 annual festivals, addressed to music, urban dance, theater, performing arts, and so forth.

The regional museum system has brought together nearly 150 public and private institutions thanks to the initiative of

3. The Roots of Dreams, feature film by Francesca Zerbetto and Dario Zanasi, 2014. Still image © Dario Zanasi_ Francesca Zerbetto.

4. The Roots of Dreams, feature film by Francesca Zerbetto and Dario Zanasi, 2014. Still image © Dario Zanasi_ Francesca Zerbetto.

5. DumBO - Multifunctional urban district of Bologna, former Ravone railway yard, Bologna, Robot Festival 2019. Photo © Robot.

6. Herbert List, Tuna being hoisted up after the catch, Favignana, Italy, 1951. FOTO/INDUSTRIA 2021. Collezione MAST. Courtesy of The Herbert List Estate / Magnum Photos.

the former Institute of Cultural Heritage (IBC – Istituto dei Beni Culturali), today the Cultural Heritage Service. Since 2021 in collaboration with the Region, ART-ER and the Clust-ER Create, the Cultural Heritage Service has promoted meetings specifically addressed to the digitization of Museums and Theaters, in order to bring together demand from institutions for updating digital cultural heritage models (cataloging, display, fruition, communication) and the supply of technologies for enhancement the CH in multiplatform mode. In December 2021, with the release of the online platform emiliaromagnaosservatorioculturaecreativita.it/, ART-ER has initiated a process that aims to integrate different repositories, in order to offer a quantitative reading of the CCI phenomenon.

Since 2020, the Research Center for Interaction with Cultural and Creative Industries within the University of Bologna and the Digital Humanities Center within the University of Modena and Reggio Emilia were established, thanks to funding provided through a regional call for proposals for the activation of research laboratories to develop territorial impacts through research-actions exploiting enabling technologies.

Both laboratories are mediating infrastructures that enable digitization processes in different cultural and creative fields. The synergy between the two centers and the open dialogue with ART-ER and the region, have led to the development, among many other projects, of the CCI Space.

This online platform is promoted by CRICC in collaboration with Flaminia Foundation. The aims is to observe, analyze and offer a qualitative reading of the region's creative and cultural metabolism, focusing on the narrative of the relationship models through which CCIs meet and collaborate. Among the patterns that emerged in the research approach through surveys, interviews with actors in the system, it is evident that engagement between different actors occurs through relational processes and mutual knowledge. The design of the Stories section was set through content storytelling that reflected the actual metabolism of the encounters, the digital fruition and the user experience. The aim is to map the various CCI through hypertext narratives, linked through keywords, which allow a set of tags to be related to each other. Each tag can be considered a node in a narrative network and is the outcome of a direct or indirect relational encounter. Within the CCI Space, plural reading paths are possible and aim to describe the articulation of meetings and relationships. The care in proposing a more personal interaction between user and content related to people, places and cultural and creative products and services was influenced by an additional line of research conducted by CRICC, in collaboration with the Advanced Design Unit of the same university, dedicated to Human Body Design. This area of research activated a second repository about cases and practices related to the body-human-machine relationship. The online repository was presented at the Future Design Human Body Interface International Symposium in June 2021. While the CCI Space platform was made public in September 2021 during the CCI Days Festival, an event produced by CRICC to celebrate culture, creativity and the realities belonging to the CCI sectors. A series of workshops (related to new emerging profiles) were also developed during CCI Days, and among them, the *Body Interaction. Human and Rhythmic Communication* explored ways in which technologies can effectively dialogue with the body through the use of features inherent in sensory channels. The goal of CCI Days 2021 has been to highlight how much research, innovation, experimentation and enabling technologies can be put at the service of institutions and businesses, create new products and services, enable cross-overs in different productive sectors, generate new economies, and activate new behaviors.

Connections with regional, national, and international networks, through dialogues with curators and managers of centers for innovation and creativity, also allowed to explore the value of interaction with other European ecosystems, in order to multiply the impacts and effects of these relationships.

### *Designing relationships through virtual bodies and physical spaces: from digital to real cultural and creative hubs*

The public presentation of the CCI Space platform during the CCI Days 2021 contributed to recognize it as remarkable prototype to be adopted as a designing tool for the creation of the Emilia-Romagna cultural and creative hub.

In fact, since the last few years, the idea promoted by ART-ER is establish a creative hub, a hybrid one-stop-shop that provides, in addition to the physical dimension, virtual access via an online platform.

7. Paradisoterrestre Editions, the historical art and design brand founded by Dino Gavina. Bologna Design Week 2019. Photo © Mattia Tonelli.

On the one hand, the hub will be aimed at integrating and systematizing skills, infrastructures, equipment, initiatives and actions developed on the regional territory in favor of the CCI sector, its development and its innovation, and will represent a facilitated access method to all the opportunities available.

On the other hand, the hub will act to encourage operational collaborations between the various territorial actors by promoting open innovation that focuses on the integration between new technologies, in particular digital, and cultural and creative skills.

The action of the hub will be aimed at stimulating the digital transition of the various subsectors of the CCI system and, at the same time, supporting the competitive growth of the regional production system in general, facilitating collaborations, intermediated by specialized figures, between traditional companies and CCI companies.

The methodology in the creation of the CCI hub will follow three main actions:

Action 1_Establishment of a multi-stakeholder steering committee which intends to develop governance mechanisms that can improve the fragmentation of the regional cultural and creative ecosystem, generated by its heterogeneity. The aim is to develop greater integration between different territorial stakeholders on the interaction between art, technology and traditional industries, promoting collaborative decision-making processes.

Action 2_ Establishment of the Emilia-Romagna cultural and creative hub which implies the design and implementation of a tender for the financing of a cultural and creative regional hub to foster cross-sectoral collaborations, the development of skills, creativity and innovation.

Action 3_ Establishment of a task force for the synergic development of regional measures, to encourage the improvement and innovation of regional calls dedicated to CCIs and to promote greater integration with new technologies and cross-fertilization with other production areas.

Designing all these actions will imply the improvement of one-to-one relationships between all the different actors involved in the establishment of the physical space. The network of relationships will be mapped and communicated through the site which will be the digital CCI space for access to plural consulting services.

*Designing relationships between virtual bodies and digital spaces: Culture & Creativity Knowledge and Innovation Community*

As part of the New European Bauhaus initiative, and within the framework a connectivity, digitalization, and climate change transition, the European Institute of Innovation and Technology (EIT) (EIT Culture & Creativity, s.d.) has envisaged the creation of a new Knowledge and Innovation Community (KIC) in the area of Cultural and Creative Industries and Cultural Heritage. In fact, CCIs are considered major drivers of economic growth and job creation throughout Europe. EIT Culture and Creativity is intended as a pan-European platform to support Europe's recovery and cohesion. The release of the call for proposal for this new KIC took place in October 2021, the evaluation process concluded on June 23, 2022 with the selection of the string promoted by ICE – Innovation by Creative Economy consortium. The ICE consortium, led by the Fraunhofer-Gesellschaft, is composed of 50 partners from 20 European countries: Italy is represented by the National Research Council (CNR), the University of Bologna through Una Europa, the Emilia-Romagna Region by ART-ER, as well as many other public and private entities.

The ICE partnership will operate through six Co-Location Centers, in Amsterdam, Barcelona, Bologna, Helsinki, Kosice and Vienna. The call stated that a Co-location Centre should be located in one physical location, and it will be up to applicants to justify that the proposed site for a Co-location Centre meets the requirement of "physical proximity". Bologna Co-Location Centre will see ART-ER as the host partner and will be physically located at the Tecnopolo, the former Manifattura Tabacchi, which will host also the European Centre Medium Weather Forecast (ECMWF).

Indeed, the Tecnopolo Manifattura will not just be a data center equipped to provide services to multiple clients, but a sort of a physical and web factory, a network that will channeling the needs and expectations of local and regional systems, providing services adapted to each reality and stakeholder groups (students, startups, investors, institutions). For expanding and drawing relationships, the strategy envisions that the Bologna Co-Location Centre will target the Mediterranean area. It will support the processes of innovation, digitization and collaboration of the entire CCI system, providing the development


8. CCI Space interface © CRICC - Research Center for Interaction with Cultural and Creative Industries, Fondazione Flaminia.

of new products, services and market opportunities having as reference the cultural heritage, performing arts and creative sectors, without forgetting the human development's concept as a process of enlarging people's choices (UNDP, 1990).

## Human Body Design in incorporeal cities

> Culture is not only our common language, it is also an innovating ecosystem. The new EIT Culture & Creativity Innovation Community will capitalise on the unique richness of European diversity to ensure that creatives are ingrained in the pan-European Innovation Ecosystem.
> Mariya Gabriel, 2022

In the creative disciplines, the search for new tools, techniques and technologies for the production of meaning has always accompanied the most avant-garde experiments. These experiments anticipated inventions and/or the adoption of tools, borrowed from other fields, to empower the body of the producer (artist, performer, designer) and the user. Culture and creativity have always been embodied and materialized in products, services and performance events.

Today, the challenge that invests research across disciplines, CCI practices and policies is to preserve this "embodied creativity" (GRIFFITH, 2021) in increasingly disembodied contexts.

The issues about the effects on bodies of the coexistence of reality and the digital, of the interaction between virtual and real ecosystems, are absolutely topical. Plural positions can be found in the reflections on *onlife* existences (Floridi, 2015), on movement and our interactions in the spatial dimension as the foundation of our thoughts (Tversky ,2019), on the alienation of proximity in the digital with the erasure of bodies and the sensible fall that follows (Le Brun, 2020), on the digital order that has taken over from the earthly order (Han, 2022). Therefore, the thoughts elaborated in this contribution are intended to offer additional space for attention for the future of the role of CCI and its impact on bodies, behaviors, and cities.

In fact, as also confirmed in the meeting at R2B 2021 titled *Platforms, Data and Artificial Intelligence: New Models of Social and Cultural Spaces*, policies and the design of specific calls to support CCI can determine the future course of the entire country, which for culture, creativity and cultural heritage has always been recognized in its unique trait of materializing culture and creativity that is intrinsically identity-driven and *made in Italy*.

Policies can create the conditions and enable those with the ideas to develop them, facilitate the chances of success, implement processes to protect micro creative realities, to provide them with the right of existence, fostering and expanding their metabolism through interaction with international interlocutors.

Digital *endless spaces* can enable ecosystems, encounters and original interactions between culture, creativity, and cultural and creative productions. However, the need to converge in physical spaces remains as an all-human way of conceiving life as the encounter with the other than oneself.

On the one hand, the hope is to capture elements of balance in this conjuncture full of great funding for creativity, and on the other the great need for balance between embodied creativity and digital dematerialization of culture. Design can play this mediating role in order to direct projects in order to fund actions, tools and processes for the design of new cultural and creative products and services that influence new cultural and social *bodies*, prototypical solutions, based on the centrality of the body, the need for real encounters and the need to feel belonging to *limited spaces*.

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# HUMAN BODIES,
# SYSTEM AND MACHINE INTERACTION

# AI INTERACTION SCENARIOS FOR HUMAN BODY DESIGN

*Andrea Cattabriga**

While it now pervades many of the products and services we use on a daily basis more or less without being aware of it, Artificial Intelligence (AI) remains a debated paradigm at all levels, from the technical to the ethical and meaning-based ones (Hawley, 2019). While we can safely overlook any agreement around definitions (but being satisfied with defining AI as a counterfactual concept (Floridi, 2021), as designers we need to understand, in addition to its properties and potential, what effects AI entails from the point of view of its use in the design process. AI is "the field that studies the synthesis and analysis of computational agents that act intelligently" (Poole & Mackworth, 2018) and incorporates many families of algorithms (Domingos, 2012).

And it is precisely the relationship between mind and body that is one of the main conceptual issues, underlying the theories that have directed the technical developments of the approaches we put under the AI umbrella. For example, Artificial Neural Networks (ANNs), whose realization led to the construction of Deep Learning models, simulate brain processing by using simplified units that approximate the integration and activation characteristics of natural neurons. While these models are capable of impressive results, considering, for example, the ability to identify rare diseases or generate an image from a textual description, they do not demonstrate to possess knowledge of their own (Hawkins 2021), nor to perform simple algebraic calculations. Human design role is fundamental in defining learning goals, learning rules and network architecture.

As suggested by Caronia (2002, p. 240) in the light of the proximity of technologies to the body and the digital pushing an ontological shift[1] of our world, technology is no longer merely a prosthesis of humans, but part of an increasingly nuanced continuum. A path from the post-human to the transhuman pushes design to deal with increasing complexity, made up of

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non-linear processes, overlapping agentivities, new technological constraints, the dimension of data, uncertainty of algorithmic outputs, and new ethical challenges (Forlano, 2017; Clark, 2017).

We are in the era of the most generalized invasion to which the human body has ever been subject to (Caronia, 1986b, p. 69) and regular interaction with AI will probably end up changing our minds as well (Caronia, 1986a, p. 90).

In this section of the book, I will propose a view of the relationship between AI, bodies and agents through an ontological mapping attempt of AI-driven design spaces. The idea here, is to interpret an increasing interdependence between the biological and the artificial, orienting designers in the navigation of such a complex interdisciplinary space where AI increasingly appears to be a decisive approach.

## AI and body

As explained by Pasquinelli (2019), algorithms are not concepts exclusive to the industrialized West, but ancient systems for the organization of physical space, that served as a medium between humans, their bodies and the metaphysical. The encoding of information in the form of wearable, visual and mathematical languages has pervaded world history, with examples ranging from the patterns of Zulu anklets (Bristow, 2021) to the logic of Inca quipu (Ascher & Ascher, 2018). The relationship between algorithms and the body, before the attempts to imitate animal brain, lead humanity to try to resolve the body / mind dichotomy. A dispute that goes back to the Cartesian conception of reality, interpreted in terms of the distinction between material body and immaterial mind, a perspective that inspired the idea of cognition as a computational process. Researchers from a variety of disciplines counterargued this thesis showing how intelligence and body are two aspects of the same thing (Bratu, 2019; Mitchell, 2021, pp. 6-7). Historically, this paved the way for further theories around AI, body and environment such as embodied cognition (Cangelosi et al., 2015) up to the frontiers of integration between the biological and the artificial (Damiano & Stano, 2018). But despite the giant strides made in building AI since the 1950s, our way of conceptualizing it is certainly still flawed and goes hand in hand with our still limited scientific understanding with respect to the nature of intelligence; as noted by some observers we are probably in an era where AI is closer to alchemy than science (Mitchell, 2021).

AI entered our bodies indirectly, with the first diagnostic decision support systems in the early 1970s (Kaul et al., 2020), and then directly, starting in the 1990s with the first intelligent knee replacement (Nayak & Das, 2020), finding applications in many fields from brain interfaces controlling prosthetic and orthotics devices (Vujaklija et al., 2016), to applications regarding the mental health wellness (D'Alfonso et al., 2017). The reason for this progressive penetration of AI into the body is consistent with two converging dynamics. First, the need to interpret a wide variety of necessary behaviors and reactions to environmental or intentional stimuli, which are not always predictable (thus clashing with the limits of classical programming that deterministically associates "if this is true" with "then do this"). Second, the need to effectively process large amounts of data from sensing and measuring body parameters generated by devices and applications (Lupton, 2016).

## Framing Design with AI

The scientific uncertainty around core AI-related concepts, the pressure towards early adoption in every industry and the challenges it poses in the development, put even designers on a path of exciting experimentation and simultaneous strong disorientation.

Over the years, several concepts have been associated with the challenges that UX designers face in integrating intelligent systems into their practice. Among those reported by Yang et al. (2020). I found the most relevant to be human-AI interaction design, AI/machine learning as design material, the design of intelligent systems and designing for/with data. This is important due to the strong multidisciplinary nature of issues involving the design of experience with AI agents.

Framing the relationship between design and AI is a relatively young and interdisciplinary process (Zdanowska &

Taylor, 2022), which will involve adapting typically user-centered methods, to a structured approach to the complexity management of AI-based systems. In addition, it will prove central to move away from the application of traditional product development techniques no longer suited to the complexity of AI-based systems (such as UCD or Design Thinking), and integrating ethical considerations by design into the process (Tolmeijer et al., 2021). AI poses issues at every level of the design process, as tools with an inherit power transforming the role of the designer (Lim & Jung, 2018), as a fundamentally non-deterministic outcomes generator (Zdanowska & Taylor, 2022), and because substantially what makes AI powerful for designers is what makes it difficult to deal with.

However, several research projects are trying to surface useful knowledge for designers when engaging with AI, such as AI's technical complexity, high demand for data, prototyping and testing challenges. For example, Holmquist (2017) has identified several interdependent challenges that relate specifically to interaction design and Yang et al. (2020) framed two AI systems attributes such as capability uncertainty and output complexity as factors to navigate design challenges.

Recurring among different branches of the design discipline is the need to overcome human-centered approaches in relation to AI, and for various reasons, from the merely ontological (other living beings deserve to be represented in design processes) to the more technical ones (the systems we are confronted with present novel characteristics to which we need to adapt the practice). New philosophic approaches such as flat and object-oriented ontologies, new materialism, posthumanism, and others (Cruickshank & Trivedi, 2017), are indicating that in contexts such as the Internet of Things, the will of the human is mediated by the agency of the non-human generating new types of tensions and questioning the centrality and primacy of the human being.

## New AI scenarios for Human Body Design

The framing of the relationship between AI and bodies from the perspective of high-level UX and interaction design is open to several interpretations, depending on the purpose we wish to pursue. In order to offer an interpretive rather than an operational perspective, I propose to navigate this complex space using agents theory and a new classification approach to the AI-mediated systems, by immersing this technical level in a more epistemological one related to the need to reframe our relationship with technology, our identities and other living beings.

## Bodies as gents and their AI-mediated interactions

Poole and Mackworth (2018) in their seminal work, define AI as "the field that studies the synthesis and analysis of computational agents that act intelligently". The agent consists of a body and a controller which receives through the body perceptions of the environment and imparts commands to the body. According to many authors, agents can be classified according to many criteria comprehending intelligence, cognitive approach, structure, nature, knowledge system, function, autonomy, cooperation, and competition level (Burgin & Dodig-Crnkovic, 2009). Deriving from the world of AI, the interpretation of reality through the concept of *agents* and thus their nature (biological, artificial, hybrid, etc.), turns out to be of utility. Indeed, an agent can be any entity that can be seen as capable of perceiving its environment through sensors and acting on this environment through effectors (human, animal, plant, software, etc).

This way of looking at us and other entities embraces on the one hand a pluriversal perspective, the one, and accommodates the complexity of relationships in an ontological perspective based on relationality (Escobar, 2018). On the other hand, that tension to overcome the human condition towards a posthuman philosophy that opens to a relationship of possibility with technology, just and liberating (Braidotti, 2006), with a vision that shifts from the body to embodiment, conceiving a less structural perception open to continuous transformations (Hayles, 1999). The space of the cyborg, in the words of Caronia, is the ensemble of processes that occur at the boundary between man and machine, and that's ultimately resembling a problem of interfaces (2008, p. 70). But it is with an other-than-human conception (Blanco-Wells, 2021), open to a multiplicity of ways of existing (non-human-centered), that I want to counterbalance the risk that visions based too much on agentivity and vitality might extinguish that hermeneutic force that characterizes living beings and their way of making the world (Beinsteiner, 2019). The contradictions or inconsistencies that certainly some scholars might find in looking at the proposed mapping, I hope can be forgiven in the light of a certain representational pragmatism necessary to make this work useful for practitioners.

Below are the proposed categories of agents:

- body: (human) body, organs, brain, limbs, expandable with body extensions such as prothesis, implants, extensions;
- other humans (related to intra-specific interactions);
- other bodies, groups, community, society;
- other-than-human (related to inter-specific interactions): animals, plants, bacteria, a mountain;
- avatars (or virtual self): virtual reality avatars and other form of simulations of ourselves in other dimensions;
- muti-agent systems: (comprehending single artificial agents) devices, wearables devices, vehicles, robots, drone swarms, and so forth.

At a general level, the list contains agents equipped with a body except for *virtual self* and some *artificial agents*, which, however, may possess sensors and actuators – and thus a sort of corporality – appropriate for the virtual worlds or data-spaces in which they are located (Allbeck & Badler, 2002).

In multi-agent systems, it is possible to look at the system from two perspectives: that of the agent and that of the interaction between agents, defined through the concept of sphere of influence. Depending on the overlaps occurring between the spheres of influence, different types of dependencies (interdependence, unilateral, mutual, reciprocal) can be identified (Hadzic et al., 2009). In the present discussion, this view of spheres of influence is the one that generated the mapping of agent relationships.

Another important principle – in terms of usability – for the classification of interactions is focused on a definition of agents and their characteristics as a system of emergent properties, dependent on the morphology of the relationships in which they are involved (Callon, 1999). The interaction between AI-mediated agents must focus on the contingency of action, assuming that the coherence of action is not fully explained by either pre-existing cognitive schemas or formalized social norms (Suchman, 2012).

The perspective of the following mapping attempt (fig. 1) is based on a distribution of agents according to two main axes: from a condition of intimacy to one of plurality; between biological and artificial nature. The relationships established, try to comprehensively describe the interaction dynamics between agents, identifying peculiar spaces for design research. The terminology adopts a human-body point of view but tries also to accommodate a model suitable to explore the perspectives of bodies from other species.

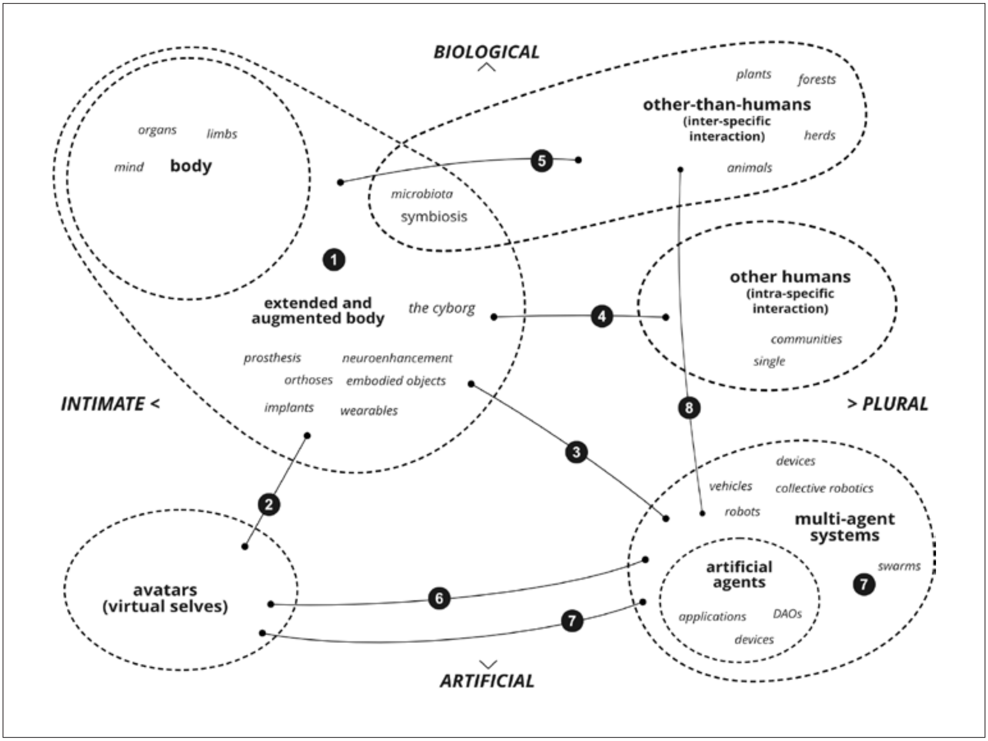
Categories of AI-mediated relationship among agents:

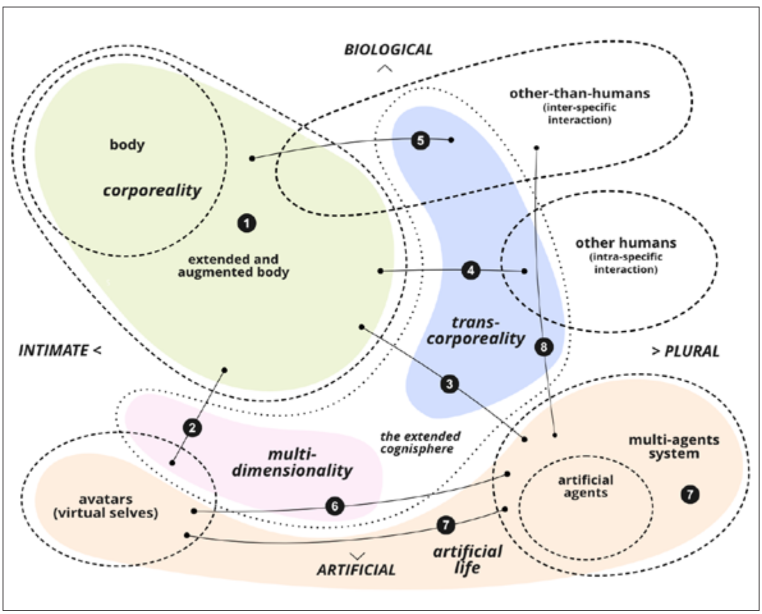
1 - body coordination;
2 - body interaction with virtual selves;
3 - body interaction with artificial agents;
4 - body interaction with humans (intra-specific interactions);
5 - body interaction with other-than-humans (inter-specific interactions);
6 - virtual selves interaction with other artificial agents;
7 - artificial agents interaction with other artificial agents;
8 - artificial agents interaction with non-humans.

## Clustering design spaces

Elaborating on this agent-based epistemology, I propose a further classification that clusterizes interactions, through the identification of 4+1 specific conceptual spaces (fig. 2): corporeality, artificial life, trans-corporeality, multi-dimensionality, and the extended cognisphere.

The categories of interactions are described below with some specific examples given.




1. Mapping AI-mediated interactions among embodied agents.

2. Clustered spaces of AI mediated interactions between bodies.

*Corporeality*

The first category includes the bodily dimension of biological entities – both human and non-human – and including everything that corresponds to a dimension of affective, motor, or spatial embodiment (de Vignemont, 2011). Corporeality is viewed here as an extended or post-human quality that includes anything that can be traced back to body ownership (Kilteni et al., 2012), from prosthetics, to peripherals that can be installed to augment or substitute perceptual capabilities or non-biological functionalities (a recognition chip, a synthetic limb, a neural implant, etc.) and even tools.[2] AI already finds application in coordinating between the biological body and parts or in managing the operations of artificial components such as prosthesis and implants (Nayak & Das, 2020), measuring particular statuses (Maret et al., 2018), interpreting emotions (Picard, 2008) or supporting experiences based on dynamic quantification (Oh & Lee, 2015). Given here that the human body is composed of human and non-human species living in symbiotic adaptation, AI can also be used to monitor and regulate these relations (Macnaughton, 2020, as cited in Ağin & Horzum, 2021).

*Artificial life*

The artificial life space contains the interactions occurring between fully artificial agents of different natures and of varying complexity (individual applications, connected devices, autonomous vehicles, humanoids, etc.): all those that are in practice artificially generated (to which, however, biological parts may be added). Highlighted in this category, as separate entities are avatars (or virtual selves), which differ from other types of artificial agents in the particular connections and relationships they have with the beings of which they are the simulation, and with whom they collaborate (Juul & Klevjer, 2016). AI in this space is characterized by complete pervasiveness as the vital fluid of these systems. Applications range from classical sense-motor coordination functions, situated or distributed cognition (Ferber, 1999), to more specialized ones concerning social behaviors, and especially to the simulation of the environments in which agents move.

*Trans-corporeality*

This is the category of the interaction between embedded agents (of any nature), which are those equipped with a body through which to explore, physically interact, perceive and act on other bodies. This space is the one of the phenomenal, perceived world, a reality of constant change through relations (Kang, 2014), where a new epistemology of inter-specific encounter is being built (Marchesini, 2015) and where "bodies are intermeshed with one another, mutually affecting and being affected by each other" (Bryant, 2014). AI tasks here are variegated, from mediation and communication, to experiments in the direction of the more-than-human interaction (Coskun et al., 2022). They include new interactive technologies for animals, the involvement of living organisms as research partners (Mancini et al., 2012), and investigations around how to do design and research with nonhumans (Giaccardi, 2020). Other biological-artificial cooperations, are based on the simultaneous interaction between different and hybrid agents, ranging from art performances (Piplica et al., 2012) to surgical teleoperation with humanoid robots (Stanton et al., 2012), to mention a few.

*Multi-dimensionality*

Trans-dimensionality is the space where it is performed the relation between bodies and their avatars (or virtual selves), representations, reproduction, and simulations living on another dimension, but to which there is a special connection, different from that with other generic artificial agents (Evans, 2012). It is the space of metaverses, of simulated worlds such as those in video games,[3] in which avatars can function under our direct control or in complete autonomy, but it is also that of "suspended" assemblages, which transcend the corporality of individual worlds (Hauschild et al., 2007). AI is thus in a condition of multiplicity, supporting coordination among agents belonging to different dimensions, sometimes synchronizing perceptions arising from bidirectional stimuli from heterogeneous environments, defining behaviors transduced from our physical to virtualized selves in a sort of intercorporeality (Ekdahl & Ravn, 2022), experiencing in our place the virtual sociality.

*The extended cognisphere*

The last super-category, which includes trans-corporeality and multi-dimensionality, is the space of the extended cognisphere (Hayles, 2016), where a system of interacting entities demonstrates its own and emergent properties, where the dynamics of interaction become complex, where prototyping and simulation become necessary tools to untangle cascading effects and systemic spillovers. The name of this space comes from the symbolic combination of two ideas. The first is the extended mind that creates a continuum with the environment (Clark & Chalmers, 1998), whereby interaction in space changes the moral sense of interacting with others to the equivalence of sociality and thought. An overlap I intend to place in the perspective of a phenomenological and subjective sphere of the world around us, a kind of "digitalized" *Umwelt* (Kang, 2014). The second idea is that of the space of the cognisphere, the dynamic and continuous flow of cognition between humans, other-than-humans and machines, a complex system of interactions in which beings co-evolve (Hayles, 2006). The extended cognisphere is thus a space of continuously interacting subjectivities, placing us at levels of intimacy we have never experienced with other beings and in which "modes of knowing are increasingly also modes of being" (Lash, 2006).

**Notes**

[1] About the digital re-ontologizying the world, see also Floridi, 2014.
[2] As explained by Gregory Bateson, a blind man's stick is a part of his body (Foxman & Bateson, 1973).
[3] Gaming as a space of experimentation in which bodies acquire a sense of relationship between worlds and in which at the same time, the separation of roles in development teams continues to remark on that historical dichotomy between body and mind (Evans-Thirlwell, 2019).

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# THE EVOLUTION OF THE HMI DESIGN. FROM THE CURRENT LANDSCAPE TOWARDS INDUSTRIAL MACHINE INTERFACE DESIGN INNOVATION FRAMEWORK

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## Introduction

When we look at the interactions between humans and machines, we may address heterogeneous factors ranging from the human experience and the quality of interaction to the system architecture, until machine automation. In this chapter we want to focus on the Human-machine interface (HMI) in the industrial domain, defined as an interface that allows humans to interact with machines and systems (Papcun et al., 2018), including computer monitors, tablet devices and mobile/cell telephones, for manufacturing and production purposes. The interface is the "space of the interaction" (Anceschi, 1993) where the functional and informative nature of the machine controls are thought to support the emergence of a valuable machine operators' and technologists' experience.

Since the 40s the new landscape of interactive products (Kepes, 1949) has been investigated as a novel kind of industrial products whose innovation is pushed by technology development. In his historical review, Maldonado (2003) states the emergence of an even-new landscape based on the wave of miniaturization and cost lowering of consumer electronics, and its application to industrial production. Today HMI finds evolutionary innovation in the fields of machine learning, material science, manufacturing processes, sensing and actuating systems, that are rapidly transforming the way we interact with technology. The authors want to explore current industrial machine interface design culture with the goal of understanding and interpreting the design solutions implemented by *best of class* interface projects and, on the basis of the results of this analysis, to claim for the need of establishing an HMI innovation framework.

The history of industrial machine interfaces has been featured in the past by HCI/HMI frameworks such as those by Shneiderman

In apertura:
1. Interaction and User interface design for a supervision system (SCADA)

et al. (2016), Nielsen (1994), and Wickens et al. (2004) aimed to better guide the design of HMIs and improve HCI by putting human user experiences, needs and capabilities at the heart of the design process. In the 60s, Man-Machine system (Cherry, 1966) has been established as a distinct area where the interaction domain is at the very heart of the reflection on modern industrial design; however it is only at the beginning of the 80s that a systematic analysis of the interface domain has emerged as leading debate in the design community, with the influence of the Olivetti, XEROX and IBM interface design projects (Barbacetto, 1987; Johnson et al., 1989; Anceschi, 1993). The authors wish to contribute to this tradition looking for current industrial machines interface design best practices and putting light to the overall maturity of the landscape. The main components of interface design are disentangled in the case-based analysis with the goal of tracing the evolution of languages and interaction strategies. Based on this analysis, we will discuss how an innovation framework might be established and evolved.

In fact, as design researchers and professionals we are used to understand the potential of the technology, such as the impact of hardware and software innovations, and we have the responsibility of the design of the aesthetic, functional and experiential aspects of interactive products. We research people's cognition and experience, such as intrinsic motivation, attitudes, attractiveness, implicit intention and assumptions, but we are accountable to elaborate this knowledge into the design of the interaction and, ultimately and concretely, in the design of the interface. That is why the ultimate goal of this research is opening a debate on the centrality of the interface in industrial machine innovation and the need for establishing a novel theoretical, methodological and capacity building framework for product innovation that keeps interfaces at the core of the design practice.

## An historical perspective on industrial machine interfaces

The recent industrial revolution in manufacturing is known as Industry 4.0. This is meant to be the fourth industrial revolution based on the concept of ubiquitous computing in the manufacturing industry (Vaidya et al., 2018). A smart factory is a representative form of manufacturing in the era of Industry 4.0, which adopted new integrated manufacturing technologies, such as cyber manufacturing systems, augmented reality (AR), virtual reality (VR), and Internet of Things (IoT) (Xu et al., 2014).

We argue that it is possible to entirely understand and interpret the current Industry 4.0 landscape only looking at what has happened in the previous industrial revolution turns (Kumar & Lee, 2022), since every change in work, systems and enabling technology has brought a paradigm shift in human-machine interfaces (HMIs) as well (Adwernat et al., 2020; Lucke et al., 2008; Monostori et al., 2016). As long as technology has innovated industry, the task and information complexity inevitably increased and consequently the need of developing HMIs for effective and efficient task performance arose.

Starting from the second industrial revolution (Industry 2.0) the electrified mass production system began, which enabled the supervision of data from the manufacturing line and controlled the integrated manufacturing process. In this era, the demand of HMIs considerably increased as they were necessary to supervise and control the system (Papcun et al., 2018).

The third (digital data) revolution owed to the introduction of computerized robots and automation in manufacturing sites (Vinkhuyzen, 2003) had produced vast amounts of data requiring computer-based HMIs enabling graphical information to be presented, and extending the possibility of capturing more information from various functions (Henderson & Card, 1986). In consequence of this shift, graphical user interfaces (GUI) have extensively broaden their adoption in HMIs to supervise automated production processes (Vinkhuyzen, 2003). At the same time process instrumentation diagrams displaying the production operations information, with the possibility of accessing every phase of the process started to be easily traceable and manageable from remotely controlled HMIs (Astrom, 1985). Operators could easily control any device on the plant using a programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) systems. The advent of SCADA system in factories for supervision of shopfloor gives the advantage of pictorial presentation of shopfloor information (Ivergard & Hunt, 2008). However, GUI had limitations in presenting SCADA-based graphical information in mobile devices such as tablets, phones, and so forth (Kumar & Lee, 2022).

Today Industry 4.0 smart factory is a representative form of the novel production site where human operators are challenged with multiplicity and heterogeneity: multiple and diverse systems, a multiplicity of actors and roles, and heterogenous workplaces, including remote work and tele operation. At first, Industry 4.0 HMIs are equipped with IoT technologies and embedded network systems to support teleworking (Xu et al., 2014). Operators can observe the manufacturing process even if they are not present at the site (Lee et al., 2015). Additionally, the production process can be supervised simultaneously by different authorized users (e.g. operators, managers, and engineers) (Duman & Akdemir, 2021). Secondly, various interaction modalities (e.g. voice interactions) can be used and a variety of automated and intelligent agents might be involved in machine operations (Pollini et al., 2021). However, although the manufacturing industry attempts to progress towards the next version with the fourth industrial revolution, little attention has been paid to investigating HMIs in smart factories from the perspective of Human Factors and Human-Computer Interaction (HCI) (Gorecky et al., 2014; Papcun et al., 2018) as well as from the perspective of interaction and interface design.

## Case-based analysis: approach, dimensions and selected cases

Case-based evaluations focus on the systematic analysis of projects. In this research the cross-case analysis leverages upon the selection of a number of case studies analyzed with the same headings in order to generate findings, lessons and conclusions across multiple design projects. The research approach based on collective case studies is useful to understand and generate an in-depth, multi-faceted understanding of a complex issue (Stake, 1995).

As for the selection of analysis dimension we argued for including aspects comprised in the two main HMIs interface functions:

- display elements can present the machine parameters, the status of the machines, the production automation information and the pictorial schematics;
- control elements are used to provide input to the machines and involve interaction models and alarm management strategies (Zhang, 2010).

In particular the analysis has been carried out according to the following dimensions:

**1. Interaction model and interface navigation**: it includes all the design elements of the HMIs which could reflect user mental models, standard navigational patterns and task-based interactive strategies. UI components (es.: input controls, menu), UI framework (e.g. layouts) and user interactions (e.g. selection, zoom in/out) should be consistent throughout the navigational and operational paths.

**2. Production automation process**: visual and interactive solutions which help users to better understand the manufacturing process and the production operations' status, predict future situations and support decision making. They include KPIs, charts, informative messages and interactive data visualizations.

**3. Schematics and system representation**: it focuses on the graphical representation of electrical infrastructure or general production processes in order to provide users with intuitive and clear information about the system. These representations could be used in both monitoring and controlling scenarios.

**4. Visual identity**: the digital user interface could be based on specific visual style (e.g. flat design, material design, skeuomorphism) borrowed from traditional UI web and mobile applications. Otherwise, custom-based visual strategies based on accessibility standards and brand style guide.

**5. Alarm management**: alarms and events provide users with crucial information about machine or system status and require them specific and tempestive actions. For this reason, alarms visual representation (e.g. color hierarchy, consistent shapes, code or text labels) and interactive strategies (e.g. pop-up messages, contextual acknowledgement) are designed to support users in critical situations.

As the interface design literature widely demonstrated (Department of Health and Human Services, 2006; Iso, 2018; Norman, 2013), display and control functions are inextricably linked in concrete components that both serve the scope to inform, show and visualize process and system data, and, at the same time, offer the opportunities for the user to interact. The case-based analysis leveraged both upon principles of interaction design and user interface design (Bagnara & Crampton-Smith, 2006; Tognazzini, 2014; Moggridge, 2007; Kolko, 2011; Preece et al., 2015; Chignell, 1990).

As already anticipated in the introduction we selected the *best of class* HMIs design cases based on the recently awarded projects related to two of the world's largest design competitions, the iF Design Award (iF Design Award, n.d.) and the Red Dot Design Award (Red Dot Design Award, n.d.). The selected projects come from the last 3 years of contest editions (from 2020 to 2022) with relation to two main sectors, based on the statistical classification of economic activities (Eurostat, 2008):

1. **Manufacturing**: it includes HMI projects for both monitoring and controlling production processes, related to craft and large scale activities.
2. **Electricity, gas, steam and air conditioning supply**: it includes HMI projects which focus on monitoring and controlling activities related to providing electric power, natural gas, steam, hot water and the network of lines, mains and pipes.

## Today industrial interface design landscape

In this section, we will describe the main design strategies related to the HMI projects selected for each design dimension, intended to support richer and more meaningful design solutions, according to usability and interaction principles.

*Interaction model and interface navigation*

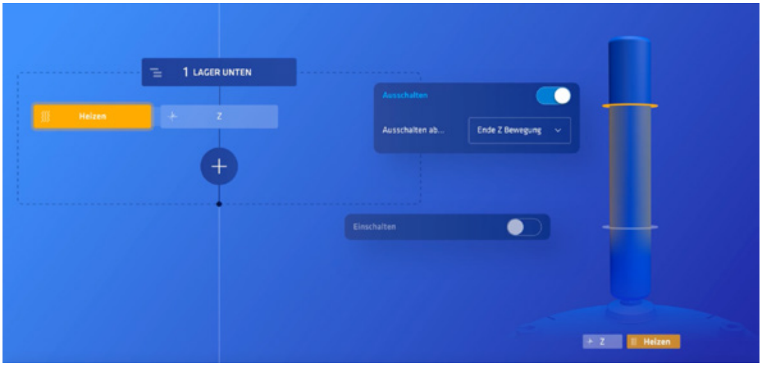
EMAG DNA (Edna, 2020) is a modular ecosystem of interconnected software and machine components in metalworking factories. The HMI addresses different scenarios in a multi touch panel, from the setup of a machine, its operation and the process monitoring. Production data is graphically displayed with a 3D representation of the machine, which also clarifies the tools' status. In figure 1, the user is guided to create a machine process through a sequence of predefined steps called *EDNA Nodes*, available in a contextual library.

*Production automation process*
In LMS LIFE (Lms Life, 2021), the HMI has been designed to monitor the performance and efficiency of production machines in manufacturing IoT. The design concept focuses on intuitive infographics used to showcase the collected data. The goal is allowing the user to reduce errors and optimize production. The navigational model is based on a drill-down principle that enables users to get a panoramic overview of the plant and enter in the machine details to identify anomalies (fig. 3).

*Schematics and system representation*
In KIEFEL HMI for packaging machines (Kiefel - Hmi, 2020) the user interface is based on a modular machine visualization that guides the navigation and displays the production status. In figure 4, illustrations and animations highlight the production process and the program configuration has been designed including only the main important parameters.

*Visual identity*
SIG CRUISER (Sig Cruiser, 2022) is a user interface design project for filling lines. The visual style reflects the client brand identity for digital environments (e.g. website). The HMI includes graphical elements (e.g. colors, shapes, backgrounds) which has been well balanced to be applied in the industrial domain (fig. 5).

*Alarm management*
In South Stream project (South Stream, 2022), the HMI aims at supporting users in monitoring and tracking anomalies of offshore gas pipelines (fig. 6). This complex system is continuously exposed to several environmental factors which need to be displayed in an efficient way to the operator in order to improve the situational awareness. The approach adopted for the alarms representation focuses on a graphical strategy on different layers of details: from the overall pipeline where anomalies are displayed as circular elements, to a 3D representation of the pipeline in which the alarm occurred. All the data gain the same color of the anomaly priority (e.g. red, yellow).




2. EDNA Nodes, interactive strategy to support users in creating production processes by using a library of single steps. Retrieved from: https://www.red-dot.org/project/edna-the-ecosystem-for-production-processes-and-the-future-of-the-connected-factory-48347.


3. Example of Line 1 data production. It includes general performance, daily effectiveness, top 10 failures, product counter and a summary of machines performance. Retrieved from: https://ifdesign.com/en/winner-ranking/project/lms-life-next-generation-line-monitoring-system/312701.


4. KIEFEL - HMI based on illustrations and animations of the machine components. Each machine component is represented by a specific icon, including a color status, and placed in line with other line components (modular solution). Retrieved from: https://www.red-dot.org/project/kiefel-hmi-for-packaging-machines-49301.


5. SIG CRUISER interface of filling machines which adapts the visual brand language for the industrial environment. Retrieved from: https://ifdesign.com/en/winner-ranking/project/sig-cruiser/350131.


6. The information displayed contains data that highlights, throughout a consistent color strategy, potential anomalies and risks. Retrieved from: https://ifdesign.com/en/winner-ranking/project/south-stream/346829.

## Case-based analysis results

In this paragraph the main insights from the case-based analysis are being described and discussed.

Visual manipulation: among the crucial aspects emerging from the analysis one is related to the development of an interactive strategy based on simple, ready-at-hand tasks, such as selecting a predefined step from a library to build a machine program, or machine components and process phases on graphical representation in order to get access to more details or to change specific parameters. Feedback and alarms' representations are moving from more conventional abstract messages to visual consistency and material methapors, for example by specific user actions on 3D models through which consistent interaction patterns are built.

Hierarchical navigation of the system: a second aspect to be noticed is the hierarchical navigation structure to access manufacturing process information from a general overview (e.g. plant) to the machine component level depending on the case and the task the user is involved in. The informative structure provided to the users focuses on a clear color strategy which helps users to identify the informative context of each event at the needed level of the structure. These strategies help users in understanding the manufacturing process according to the task and the specific user requirements.

Awareness: it's common to all the cases that process and system representations reduce users' information overloads and increase situational awareness. Visual elements, such as a production graphical representation and machine components illustrations and animations, might support process monitoring and control throughout simple and intuitive access to machine. This strategy also facilitate machine operators in program configuration by reducing complexity and user familiarization time.

Coherence and consistency: industrial HMIs require one consistent visual identity. First, by referring to the manufacturer brand style guide, by using UI elements in balance with ambient lighting and colors of the industrial setting; and second, by defining a clear and well-structured aesthetic design which supports usability and user-performance. These approaches are necessary to guarantee a consistent visual concept to be recognized among different machines and sectors (e.g. digital), delivering contemporary and modern aesthetic appeal and attractiveness for the users.

Cognitive resource saving: alarms' management has been always crucial for industrial machine or process assessment. Successful HMIs load user attention only when risks occur by emphasizing proper color strategies, such as differentiating alarm priorities and severity with colors. When this approach is coherently applied in the different layers of alarm details, and troubleshooting strategies, text descriptions and contextual actions are implemented, then the users are facilitated in solving problems and managing possible errors.

## Towards a HMI design innovation framework

In today's interface design landscape there are magazines, blogs and communities promoting the user-centered culture, the application of user research methods and the practice with design software. Such widespread of knowledge in the professional domain makes the practical and basic access to interface design very popular and trendy.

At the same time there is a gap in bridging the basic knowledge of consumer electronics interfaces to the advanced design of industrial machines interfaces. In the current scenario an increasing number of local innovators are experimenting for interaction transformations, by exploring technology and novel work practices. However, the scale and complexity of the HMI design challenges discussed in this chapter do force them to constantly acquire and evolve new capabilities in order to advance the current landscape and to evolve it towards systemic change.

We propose to leverage industry innovation upon learning ecosystems and collective creativity in order to increase the value of workers' engagement in the development of new systems for the workplace (Bødker, 1996; Binder et al., 2011; Stembert, 2017; Halskov & Brodersen, 2015). This approach will allow designers/researchers (experts of the systems) and the end-users to work together, and to build on their own experiences and provide them with relevant and useful resources through four key elements: co-operation, experimentation, contextualization, and iteration.

By establishing an infrastructure for engagement and inclusion of all those ones currently working with industrial machines will be possible to understand, revise and simplify their future work. The ultimate goal is to include all those ones that are excluded from work by establishing novel training pathways that will be based through a co-generation process where current and future workers may arise their voices, collecting their instances and engaging them in producing novel interaction scenarios. The history of the first industrial revolution taught that training is the most valuable mean of inclusion since, while grounded on work and human activity analysis, it allow to simplify job tasks and to let all the workforce enter the labour market.

By mean of mission driven industrial innovation pilots, the capacity building framework is intended to result in training activities for industrial innovation and to establish a community of practice sustaining self development journeys and, thus, tackling complex societal, technological, work and experiential issues connected to the evolving nature of human-machine interaction.

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UNDERSTANDING AND EXPLOITING THE DRIVER'S STATE WITHIN THE IN-CAR ENVIRONMENT: INTERACTION SCENARIOS

*Roberta Presta*, Silvia Chiesa**, Chiara Tancredi**

## Driver monitoring systems to increase road safety

It is no secret that most accidents on the road are due to driver errors.

The National Highway Traffic Safety Administration (NHTSA) estimated in 2016 that human error accounts for more than 90% of all auto accidents (NHTSA, 2017).

These errors are often due to the so-called state of the driver: distraction errors, sleep strokes, drunk driving, are some of the most glaring examples, but they are not the only ones. In fact, other attitudes or specific conditions of the drivers can also lead them to make mistakes, that is, to misjudge the road situation and make driving decisions that will lead toward an accident.

Recently, a fair amount of attention of researchers in the field of human-machine interaction has been paid to driving under different emotional state conditions (BRAUN et al., 2021; JEON, 2017; ZEPF et al., 2020).

One emotion that many studies in the automotive field have focused on is anger, as it has been shown in several studies to increase the frequency of aggressive driving behavior and the risk of causing accidents (BRAUN et al., 2021; HUDLICKA, 2017; JEON, 2017).

Another emotion being analyzed is anxiety: it has been shown in several experimental studies that inducing anxiety in participants results in a narrowing of the attentional focus (e.g., even attention with respect to unfamiliar or threatening cues). When driving, the driver in an anxious state (this is the case among others for all inexperienced drivers undergoing learning) is more likely to focus on the general part of the task and instead may overlook some details albeit relevant to safety (HUDLICKA, 2017; JEON, 2017; NETA et al., 2017).

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Boredom, for example, lowers alertness levels, makes perception slower and less accurate and in the worst cases can turn into drowsiness. The driver may therefore not be able to react to a potential accident situation, or in the worst case may fall asleep and increase the likelihood of serious accidents. It also appears that the large majority of users, even when they recognize their drowsy state, make an effort to continue driving (Jeon, 2017).

Also excessive happiness is considered as a critical condition while driving (Jeon, 2017) because it causes the subject to take decisions in a quick and risky manner, underestimating dangerous situations.

Also driver distraction and inattention can influence driver performance and his/her ability In driving in a safe way.

Driver distraction can be distinguished in *visual driver distraction* defined as "eye-off-road", and *cognitive distraction* as "mind-off-road" (Victor, 2005).

While visual distraction is easier to study focusing on the direction of the gaze of the driver, cognitive distraction is more difficult and usually studies focused on eye-movements and saccades.

Different studies showed the effect of cognitive load on drivers and its consequences, as for example fewer saccades eye movement, less attention to check the instruments and the rear mirror with influents to the driving safety (Harbluk et al., 2002).

Moreover, in case of simultaneous events of both visual and cognitive tasks, grater errors appear as well as near accidents (Kaber et al., 2012).

Beyond common sense, we cannot expect drivers to never be distracted or always in perfect serenity when driving. However, it is reasonable to believe that pointing out to drivers that, when they are in a certain condition, they may be taking more risks on the road could be beneficial: people driving may in fact decide to stop and take breaks, try to recover quickly from bad moments, try to refocus, or, in a scenario that is becoming closer and closer to everyone, consider handing over control of the vehicle to the automation.

This is where in-vehicle driver monitoring systems come in. They are becoming more and more powerful due to advancements in the fields of sensor technology and computer vision (Koesdwiady et al., 2016).

They can go so far as to understand what our *state* is while driving and give us advice or take action to benefit our own safety.

Indeed, albeit with some variation due to personality, cultural and age features, each of us knows that it is difficult not to let on what our emotions are, or to be distracted and not look like it.

Looking away from the road, using a cell phone with one hand, talking with passengers, are all potentially distracting activities that could be easily intercepted thanks to computer vision algorithms leveraging the video captured by an ordinary camera positioned in front of our driving place.

The intelligence of computing vision algorithms can also detect and classify our facial expressions, strongly related to the emotion we feel, as Ekman demonstrated since the 70s (Ekman, 1992; Ekman, 1999), because of the corresponding activation of our zigomatic and/or corrugator face muscles.

Even if we mask the emotions by controlling our face muscles, our body temperature, tone of voice, and movement style can reveal to a trained, intelligent eye what we are feeling, thus reducing the understanding of our state to a matter of sensing and classification techniques that are nowadays available and that keep in being optimized from the accuracy perspective by the scientific community.

## Understanding the driver complex state: the case of the Next Perception DMS

While distraction has been the focus of safety automotive research for decades, emotions were paid attention only more recently (Braun et al., 2021; Zepf et al., 2020).

However, in recognizing the crucial role of emotions in decision making, one can no longer disregard contemplating them in monitoring the state of the driver.

Therefore, today's efforts are directed in the identification of the so-called *driver complex state*, for example a state of the driver consisting of multiple aspects having behavioral and cognitive implications: those related to visual distraction, extra activities performed in the vehicle besides driving, fatigue, drowsiness, mind-wandering, (i.e., being overthinking while driving), and, last but not least, emotional conditions.

As evidence of the above, we report the case of an ongoing European project, starting in 2020 and to be completed by 2023, that has exactly this goal: the *NextPerception* project.[1]

Comprising more than 40 European partners, the project is aimed at developing a distributed architecture of sensors and artificial intelligence components enabling complex human monitoring functions, such as those of the driver monitoring system able to detect the driver complex state.

NextPerception Driver Monitoring System (DMS) is aimed at detecting cognitive distraction, visual distraction, emotion type and arousal of drivers to understand how to help them at best in safety-critical situations (Davoli et al., 2020).

To this aim, different driver's data must be captured by the DMS' sensors to have a complete picture of their so-called driver complex state, such as:

- the driver video, capturing facial expression, gaze pointing direction, and in-car performed activities;
- the driver temperature, as an indicator of the arousal level and that can be gathered by a thermal camera;
- driving performance metrics, to analyze their driving behavior;
- data coming from other sensors, ranging from pressure sensors on steering wheel or wearables, such as smartwatches or even EEG headsets, as further sources to perform more robust driver complex state monitoring and estimations.

Focusing on the combined measurement of cognitive, behavioral, and emotional factors collected through unobtrusive sensors, such a DMS is able to fuse data and obtain a 0-100 *fitness to drive* index estimating the driver's ability to have control of the vehicle.

This information about the state of the driver, combined with an estimation of the external driving environment is exploited by a Decision Support System (DSS) in charge of determining the most appropriate action to support the user: this action ranging from starting a *state recovering* strategy by means of the HMI, for example for calming down or refocusing the driver, to take over the control of the vehicle from the driver to the automation for the sake of safety. This is indeed one of the driving scenarios that is envisioned in the partially automated driving.

At the inner core of this system, however, there is the DMS with its capability of understanding the driver state, according to their behavioral and psychophysiological signals.

## Interaction scenarios

To have a look at the driving scenarios enabled by this cutting edge technology, a set of hypothetical scenarios have been developed: they show the kind of help the vehicle automation can provide to the driver, thanks to the monitoring function of the DMS.

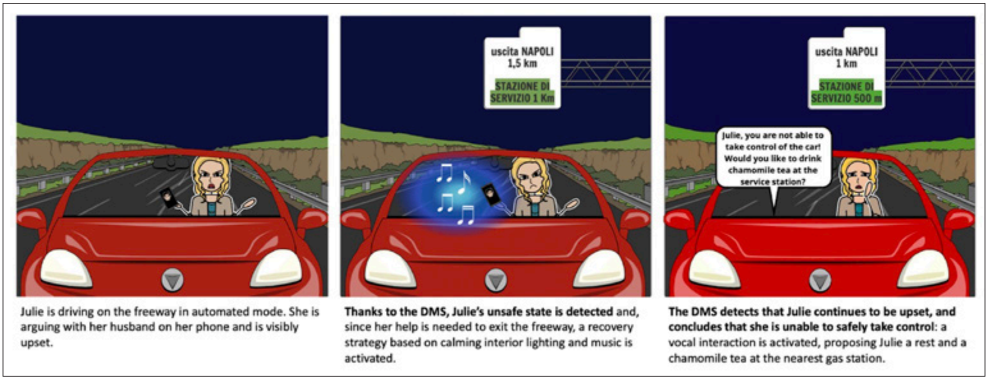
User stories are those of Julie and Peter, two ordinary people who use partially autonomous vehicles during ordinary journeys, and who for different reasons find themselves in unsuitable conditions for driving: thanks to the detection capabilities of the state of the driver, by means of the DMS, the vehicle can therefore decide to maintain / take control or to give appropriate suggestions to the driver aimed at increasing the safety level of the driver-vehicle system.

The stories have been divided into salient moments, steps, where the functioning of the DMS is key to explain and to trigger a certain behavior of the automation, shown to the user by means of the vehicle HMI.

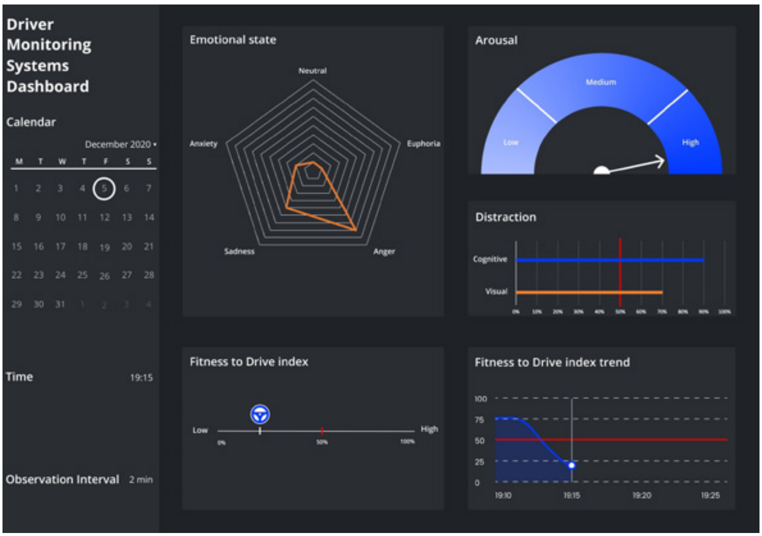
The first one is Julie's case (fig. 1). Julie, though being in the driver seat, is not actually driving, since her partially-automated vehicle can do that for her on a high-speed road.

Meanwhile, she is having a heated argument with her husband on the phone.

This is one of those typical situations in which we enter a state of agitation: we experience negative, high-intensity emotions, that is, involving a high state of activation (arousal). In such an emotional state, which can be likened to anger, our




1. Julie's scenario, enabled by the NextPerception driver monitoring system.




2. A dashboard explaining the results of the human monitoring performed by the DMS for Julie's scenario (figure 1, vignette 1).

body temperature rises, our respiratory rate and heart rate may also increase.

If there were a dashboard to inspect the different clues collected by the DMS, at the moment when Julie argues with her husband it would show us the panel in figure 2.

The dashboard shows anger as the prevailing emotional state, accompanied by lower levels of sadness because Julie's upset, since she is arguing over the phone with her husband. The activation pointer indicates a high level of arousal. The levels of cognitive and visual distraction also exceed the thresholds: Julie, in fact, is totally involved in the telephone discussion and her Fitness to Drive index is low.

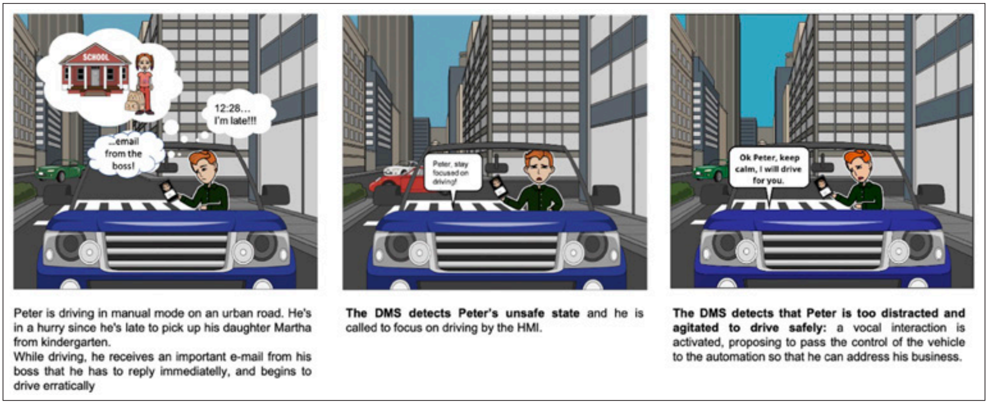
The DMS has the task of reporting this potentially dangerous state to the in-vehicle intelligence, which will know, depending on the driving situation whether to intervene or not. In the case depicted, since the vehicle is approaching the exit from the freeway and it is necessary to hand the conduction back to the driver, an attempt is made to mitigate the angry state with an emotional regulation strategy based on music and soothing ambient lighting; if it is not sufficient, as in the case illustrated, to bring the driver back to a safe state, a decision can be made to implement an emergency maneuver, rather than risk passing the control to a non-in-the-loop driver.

In the second of the reported scenarios, Peter is driving manually on an urban road (fig. 3).

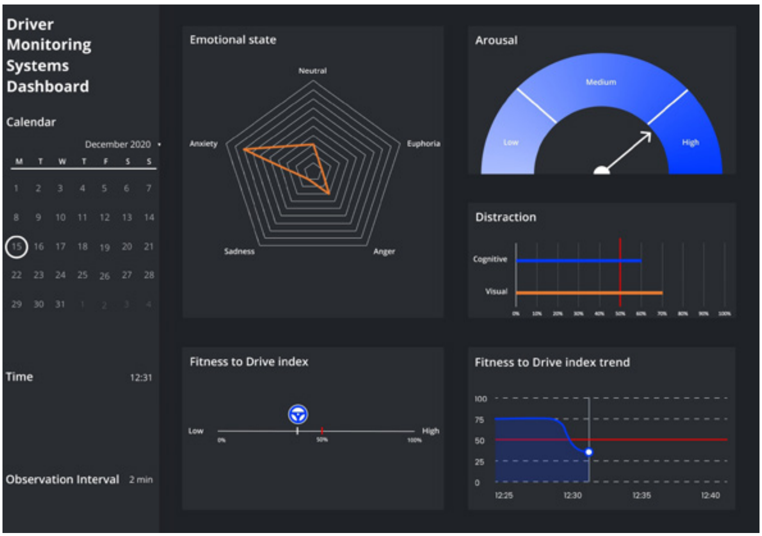
Runaway from work, Peter is late to pick up his daughter from school. We all agree that even only haste is no friend of safe driving.

Work follows him, and he begins to receive critical phone calls and emails that he should respond to in a timely manner: that distracts him, leading him to compulsively interact with the phone and, understandably, putting him in a state of anxiety, which further aggravates his ability to drive sensibly. The DMS inspection dashboard would show us something like figure 4.

An evident prevalence of anxiety is detectable. The activation pointer is positioned just beyond the threshold between medium activation level and high activation level. The levels of cognitive and visual distraction also exceed the threshold, for which significant data are recorded. Peter, in fact, takes his gaze and mind away from the primary task of driving, to




3. Peter's scenario, enabled by the NextPerception driver monitoring system.




4. A dashboard explaining the results of the human monitoring performed by the DMS for Peter's scenario (figure 3, vignette 2).

urgently use his phone. A medium-low fitness to drive index is shown.

The vehicle automation tries to recall Peter's attention on the primary tasks, but the DMS detects that the warning message was not effective enough in doing that, causing the takeover proposal in favor of the vehicle automation for the sake of safety.

## Conclusion and open challenges

In addition to the technical challenges of the artificial intelligence required to implement the monitoring function, another challenging front is the interaction with users in the scenarios presented.

As with all innovative technologies, issues concerning acceptance, that is, the degree to which future users are willing to accept in their in-vehicle lives the services offered by the monitoring system, are critical. Even with the utmost reassurances of the case, from the point of view of privacy, *feeling spied on* is a feeling that can be unpleasant, especially if the monitoring deals with our emotions, i.e., into one of those spheres that we can perceive as more intimate. Are we willing to pay this price for greater safety? Although some preliminary studies seem, at least on paper, to report a general positive attitude (Presta et al.), it is yet to be ascertained whether in practice and by effectively testing such tools over the medium to long term, the same conclusions are reached.

On the other hand, another big challenge is offered to the HMI design: how to effectively communicate to the user the why of the HMI adaptive behavior, i.e., the motivation because the in-vehicle interaction is acting in a specific way (Koo et al., 2015). The driver indeed must understand why the HMI is behaving in a certain modality, and it can be difficult to explain that is because of the long list of detected parameters characterizing the driver complex state that we have shown in the offline inspection dashboard above. This is probably the most important issue to creatively address since the HMI will represent the perceivable part of the system the future driver will interact with, hiding the driver monitoring system: it will depend on it, and on the effectiveness of the state regulation strategy, if the user will perceive the usefulness of the overall system, develop trust, and then foster its adoption.

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**Note**

[1] https://www.nextperception.eu/.

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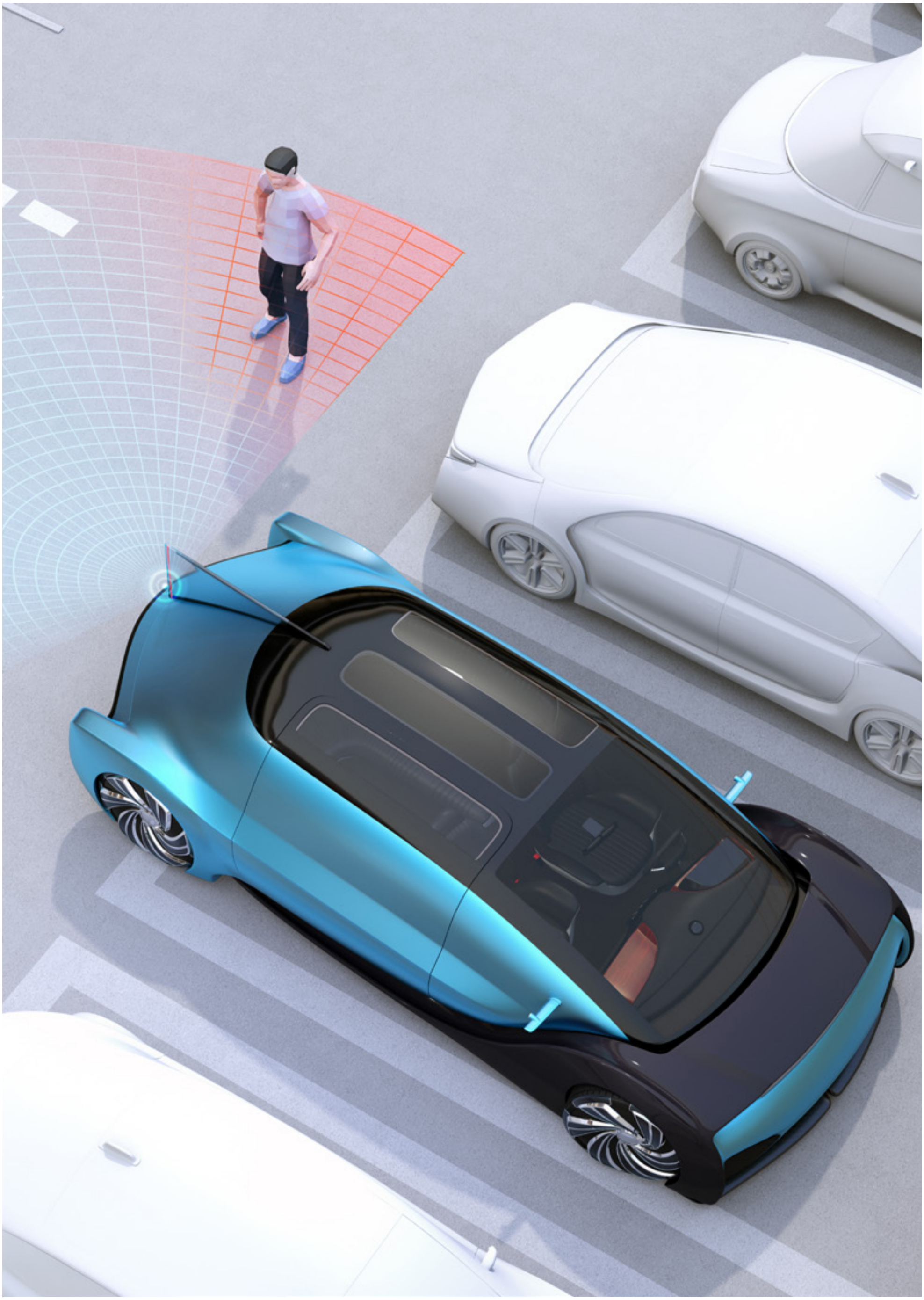

# DRIVING AHEAD - SOME HUMAN FACTORS ISSUES RELATED TO FUTURE CONNECTED AND AUTONOMOUS VEHICLES

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On the left:
1. Autonomous vehicle auto-parking with pedestrian in range.

## Introduction

Although it is not yet certain when fully Connected and Autonomous Vehicles (CAVs) will be functional on roads (if ever), there is some speculation that by 2040, most fleets will be at least semi-autonomous (Botello et al., 2019). In general, the actual vision of a fully automated car has naturally excited the public since Google won the US Defense Department's urban driving contest in 2007. Despite obvious challenges ahead, the pathway to full automation is now widely accepted as completely achievable and has rapidly become one of the most important subjects of automotive research. Automated technologies offer the capability to improve safety and mobility whilst reducing environmental impacts and it has been suggested that risky driving behaviour, errors and ultimately, crashes will be prevented by "taking the driver out of the loop". Adaptive driving support and information facilities may improve the driving experience enabling drivers to make better use of their time in routine situations whilst automated traffic management offers the opportunity to manage the road infrastructure much more efficiently providing improvements to mobility and the environment.

Against this, there are areas where these benefits may be undermined or prevented by the functionality of vehicle systems and the manner in which drivers choose to use their vehicles. Drivers may choose to drive faster believing that safety systems will prevent all crashes and injuries, or they may remove or divert attention onto other activities. Other road users may not recognize that some CAVs behave differently from human drivers. In addition, a CAV that operates well on a proving ground (with well-established and repeatable driving scenarios) may be erratic when presented with much more complex real-life driving situations. Back-office traffic management algorithms may conflict with on-board systems. Some driving scenarios may be completely unanticipated, for example vehicles with higher automation levels may interact with vehicles with lower levels of automation or other types of vehicles with unexpected consequences.

## Automation as a concept

The literature relating to several aspects of CAV implementation is now becoming prevalent. Ma et al. (2021) cite Parasuraman and Riley (1997) who defined automation as "the execution by a machine agent of a function that was previously carried out by a human". With the rapid development in vehicle technology, many in-vehicle functions that were carried out by a human before are now controlled by the vehicle. SAE, J3016 (2018) is now used to categorise the level of automation in vehicles. This is a six-level classification system, grounded on the level of human interference required. This system ranges from level 0 – no driving automation, where the driver is fully in control of the dynamic driving task in all circumstances, to level 5 – full driving automation, where the system performs all dynamic driving tasks without the need of human control in all circumstances.

Research into human behaviour relating to CAVs including user experience and acceptance is naturally gaining interest (Madigan et al., 2017). This is an important area of study, and many countries have been conducting research to assess public opinion on CAVs, for example in Australia (Pettigrew et al., 2019) the UK (Paddeu et al., 2020), and elsewhere across Europe and the world. Findings generally indicate that users see benefits in CAVs, but there are some concerns regarding safety, security, trust, and acceptance. This paper therefore looks in more detail at some of the identified human factors challenges that are likely to become relevant as CAVs become more and more prevalent on the roads in the years ahead.

## Alleviating human error

Alleviation of human error is expected to be one of the main benefits of CAVs and there is on-going research exploring this in more detail. This is reflected in an increasing number of research programmes within this field, including the Automated Vehicle Research Programme of the US Department of Transport and the Human Factors in Automatic Driving project involving consortiums of European research institutes and car manufacturers. Given that human error is attributed as being the largest contributor to crashes researchers and road safety experts emphasize that the potential road safety benefits of CAVs could be achieved by relieving the human from responsibility for driving; since CAVs do not make human errors and do not deliberately violate traffic regulations, they are assumed to out-perform the human driver and thus contribute to substantial reduction of road collisions. However, some studies express certain reservations about such expectations. There are also uncertainties associated with the interaction of CAVs with non-automated road users, particularly the VRUs, and therefore the subsequent safety effects on this group of road-users creates a cause for concern (Gonzalez et al., 2016; Hagenzieker et al., 2020).

## Interaction with Vulnerable Road Users (VRUs)

Morris et al. (2021) reviewed studies which have considered the perspectives of other road-users such as VRUs but very few studies have asked drivers or VRUs to predict exactly how their behaviours might change if they were to use a CAV or interact with one. To date, research on the interaction between CAVs and VRUs has been limited to the technical aspects of detection and recognition of pedestrians, motorcyclists, and cyclists by the vehicles, solely considered from the attitude of the vehicle (Vissers et al., 2016). However, Vissers et al. also noted that it is equally important to look at matters from the attitude of the VRUs. Will VRUs be able to effectively interact with CAVs? As an example, would this affect their crossing decisions or their red-light compliance? And if so, in what way? Would they accept smaller gaps, or would they prefer larger safety margins? Would they be inclined to infringe traffic controls such as red lights more often or not? Also, through the transition period, with a combination of fully autonomous, partly autonomous and manually driven vehicles, will pedestrians be capable of differentiating between these vehicles and would they adjust their behaviour accordingly? Furthermore, during the transition there is likely to be a large fleet of partially autonomous vehicles on the road, and these vehicles may suddenly hand back control to the human driver if they encounter a situation for which they are not programmed to handle.

A lot of research is dedicated to understanding the safety concerns around this issue; in particular whether the human driver will have the appropriate situational awareness to react to the situation in time. Returning control to a human driver who is not ready to re-engage with the driving task could have particularly severe consequences for VRUs due to their inherent vulnerability. Overall, studies on the interaction between CAVs and VRUs and answers to the questions above have received relatively limited attention (Hagenzieker et al., 2020; Twisk et al., 2013). Therefore, it is difficult to both estimate the safety effects of a transition towards automated vehicles and identify the actions to minimize the risk that interactions between CAVs and non-automated road users cause and as to whether they induce unsafe situations and accidents.

There are also the CAVs' decision-making algorithms to consider. Humans take lessons before driving alone, and it is accepted that novice drivers tend to have higher accident rate than more experienced drivers, indicating that experience is correlated to a driver's ability to drive safely. How will CAVs gain this experience? Between January and December 2019, Waymo vehicles in the US (with trained safety drivers on board) drove 6.1 million miles in and around US urban areas. In addition, from January 2019 through September 2020, the fully driverless version drove 65,000 miles and collectively these two driving scenarios were claimed to equate to approximately 500 years' worth of human driving. During this period, Waymo vehicles were involved in 47 contact events with other road users, including other vehicles, pedestrians, and cyclists. Nearly all collisions were the fault of a human driver or pedestrian, and none resulted in any "severe or life-threatening injuries". Whilst the assertions do not consider exposure factors including "near-miss events", these results do suggest that CAVs could have a positive impact on pedestrian crashes in urban areas providing sensor limitations can be overcome. Nevertheless, it should be remembered that the Waymo studies were conducted in the US which has its own unique road and traffic conditions and therefore it will be important to study the transferability of knowledge across different countries as the technology becomes more prevalent.

## Trust

As Ma et al. (2021) recognise, trust plays an important role in influencing an individual's inclination to use any autonomous system and CAVs are no exception. Trust is referred to "as the attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability" (Lee & See, 2004). The authors highlight that the driver must fully trust automation to achieve a positive outcome. Trust is said to facilitate the human-human relationship, but also in human-machine association (Sheridan, 1975; Sheridan & Hennessy, 1984). However, Parasuraman and Riley (1997) propose that a user's trust level of the automation can cause misuse, dis-use or abuse. Finding the suitable drivers' trust level is therefore required to ensure acceptance and adoption of the CAV. Previous research highlighted factors such as system transparency, technical competence, communicating uncertainty information and perceived usefulness which can all affect the level of trust in a driver (Choi & Ji, 2015; Beller et al., 2013; Helldin et al., 2013).

## Information, communication and trust

Several researchers have looked at trust and how it can affect experiences with CAVs. Communication between the vehicle and the driver appear to be crucial in this regard. For example, Choi and Ji (2015) showed that system transparency, technical competence and situation management are found to be important elements that can affect the trust level in drivers. They suggested that providing information to drivers about the way


2. What a drive of the future might look like.

3. Futuristic in-vehicle HMI design.

CAVs can work can enhance driver insight on automation. It is also suggested that driver's intention to accept or reject a CAV is determined by the perceived usefulness and trust. Furthermore, according to Beller et al.'s (2013) study, drivers that were presented with an uncertainty information (a symbol with an uncertain expression) displayed quicker and safer responses in safety critical failure conditions. They proposed that more trust and acceptance was found when an uncertainty symbol is presented compared with the control group. These findings were replicated by Helldin et al. (2013), who studied similar interest on how uncertainty can impact driver's trust in an automated driving scenario. Similar findings were found in takeover situations, where drivers had more trust when uncertainty information was provided; they were more likely to carry out secondary tasks while driving and displaying trust in the automation, compared to a control group (Helldin et al., 2013). Researchers have also directed their focus to understand how providing knowledge information of the capabilities and limitations of the CAV can support drivers' trust level (Khastgir et al., 2018). Findings show that calibrating trust with knowledge is necessary in the dynamic environment to ensure safe use and reduce the likelihood of misuse due to distrust (Khastgir et al., 2018; Parasuraman & Riley, 1997).

Although it has been suggested that providing clear driver-automation communication can significantly increase the trustworthiness of automation (Choi & Ji, 2015), finding the optimal balance between the amount of information and trust is important to prevent adverse effects as giving excessive information can increased the cognitive workload of the drivers (Lyu et al., 2017; Manawadu et al., 2018; Piechulla et al., 2003). Banks and Stanton (2016) highlight that delivering a transparent human-machine interface (HMI) display can enhance driver trust in automation. Verberne et al. (2012) suggest that providing feedback of the current automation status to the environment can potentially increase the level of trust in the driver. However, providing the right level of feedback for each user within an automated vehicle is also essential, as different users will have different information expectations and preferences (Ulahannan et al., 2020). The findings suggest that it is essential for the drivers to understand what the vehicle is doing and why, and keeping the drivers informed about the vehicle's condition is significant. Moreover, Oliveira et al. (2018) found that drivers prefer to monitor the vehicle's state and its actions during their low-speed autonomous pod ride. However, although current research has indicated that intelligent visual displays can assist in inspiring trust in automation (Häuslschmid et al., 2017; Oliveira et al., 2018), much of the HMI related studies (Banks & Stanton, 2016; Miller et al., 2016; Häuslschmid et al., 2017) are often presented in conjunction with auditory elements, such as human-like voice or the sound of beep.

Current research also fails to address whether a visual-only interface alone can provide adequate information to deliver a sufficient level of trust to drivers of automated vehicles. As part of the investigation of trust in autonomous vehicles, it will be interesting to recognise whether visual interface alone will play an important part in improving users' perception of trust in automation. It is, therefore, important to examine how trust in autonomous vehicle changes with the different level of visual-only feedback in order to predict effects that may worsen or promote the acceptance of autonomous vehicle.

## Non-Driving Related Tasks (NDRTs)

Once CAVS become fully autonomous, there is a high likelihood that drivers will have time available to partake in several other activities that are not related to controlling the vehicle – one of the expected advantages of CAVS. Several researchers are currently examining this. For example, Wilson et al. (2022) noted that various methods have been used to understand some of the Non-Driving Related Tasks (NDRTs) that will be performed in fully autonomous vehicles. These methods range from surveys specific to autonomy (Schoettle & Sivak, 2014; Kyriakidis et al., 2015; Bansal et al., 2016; Wadud & Huda, 2019), surveys and observation of activities on public transport (Kamp et al., 2011; Hecht et al., 2020; Gripsrud & Hjorthol, 2012; Lyons et al., 2007), and simulator based studies (Large et al., 2017; Hecht et al., 2020).

Many survey-based studies have aimed to investigate a range of common CAV questions around ownership, cost, and views on perceived benefits. They often also include questions relating to NDRTs but rarely focus on this topic.

There were differences in methods used, question asked, and the sample surveyed. However, there are some similarities, for example watching the road is universally scored high as is texting/talking with friends and family. Predicting future behaviour without providing additional context can also be a challenge. Hecht et al. (2020) navigate this issue by changing the context from a future CAVs to a present-day train journey. They also included additional modifiers to the scenario such as the addition of privacy to make the journey more closely relate to autonomy. Wadud and Huda (2019) also used a present-day context to their advantage by sampling chauffeur driven occupants and found large differences between journey types (leisure, commuting and business) and for inbound and outbound journeys. However, changing the context too far from the aim could affect the outcome.

An alternative method to assess NDRTs for future CAV journeys is through use of a driving simulator. Large et al. (2017)little is known regarding the nature of activities that drivers will undertake, and how these may impact drivers' ability to resume manual control. In a novel, long-term, qualitative simulator study, six experienced drivers completed the same 30-minute motorway journey (portrayed as their commute to work conducted a study in an immersive driving simulator and found participants absorbed themselves in visually, cognitively and manually demanding tasks such as using their phone or laptop. Hecht et al. (2020) took a similar approach and observed participant activities during a 60-minute automated drive. They also found the use of in-car infotainment and phone use to be high during their trial. Both user trials however were restricted in the way that the interior was designed as both used either a current vehicle or a mock-up of one. The restricted movement in the vehicle and an interior designed for driving will limit the range of activities that can take place as well as potentially limiting their duration due to discomfort.

4. Future vehicle interior workspace.

## Discussion

CAVs have the potential to offer society at large a significant number of benefits as the technology develops and matures. In fact, CAVs are already starting to offer benefits to other industries beyond the travel industry with agriculture and military being some obvious examples. The day when we are going to witness CAVs in everyday life for the regular consumer is quickly approaching. Given that Human Error is attributed as being the largest contributor to crashes, researchers and road safety experts emphasize that the potential road safety benefits of automated vehicles could be achieved by relieving the human from responsibility for driving; since automated vehicles do not make human errors and do not deliberately violate traffic regulations, they are assumed to out-perform the human driver and thus contribute to substantial reduction of road collisions.

Already, current production vehicles have advanced 'autonomous' functions that support drivers in various traffic situations (e.g., Adaptive Cruise Control, Forward Collision Warning, Pedestrian Safety). It is expected that this trend will continue, and that future CAVs will be capable of handling most of the manoeuvring and control functions of the vehicle in all traffic scenarios.

Of interest is that in urban settings, this will mean that CAVs will be required to interact with numerous other road-users. Not only would this require the CAVs to reliably detect such other road users, but it would also require that non-motorised road users will need to interact with other CAVs which are equipped with different levels of automation. Hence this could require potentially different response requirements in different scenarios for such interactions to happen safely and effectively.

Some studies express certain reservations about expectations associated with CAVs. There are also uncertainties associated with the interaction of CAVs with non-motorised road users as discussed above, particularly with pedestrians and cyclists, and therefore the subsequent safety effects on this group of road-users creates a cause for concern. So far, research on the interaction between CAVs and other vulnerable road users (VRUs – so-called as they are more vulnerable to the impacts of crashes) has been limited to the technical aspects of detection and recognition of them by the vehicles, again solely considered from the attitude of the vehicle. However, it is equally important to look at matters from the attitude of pedestrians and cyclists.

Vulnerable Road Users are clearly an important consideration regarding to CAVs but other interesting challenges and obstacles are evident as we progress towards automation. Take public perception and trust for example. At present, the public do not wholly trust the concept of autonomous vehicles. In a recent survey, 4000 drivers were asked whether they would feel safe in a self-driving car. 27% said they would feel unsafe; 24% said they would feel very unsafe and less than a quarter said they would feel safe or very safe. In addition, less than 20% found the prospect appealing or very appealing whilst almost half (45%) find the idea very unappealing, and nearly a quarter (23%) found it unappealing.

The problem of mixing of vehicle fleets is another challenge. The Eno Center for Transportation recently stated that "in theory, if you have 100% fully autonomous vehicles on the road, while you still might have accidents in rare situations, you're looking at anywhere between a 95% to 99.99% reduction in total fatalities and injuries on the road" (Thierer & Hagemann, 2014). However, to have these very desirable reduced numbers of fatalities, all the vehicles on the road would have to be autonomous. We know that this will take some time and in the interim, there will be the mixture of fully autonomous, partially autonomous, and no-autonomous vehicles on the roads. This mixture amongst the fleet could be a recipe for difficulty ahead through misunderstandings of CAV capabilities and limitations.

What about Reliability? Related somewhat to trust covered above, we need to be certain that autonomous vehicles will be safe and reliable. We cannot be totally certain of this yet. There have already been a handful of cases where autonomous vehicles have killed or seriously injured other road-users as they did not act as predicted in certain traffic scenarios. Autonomous vehicles will only be able to operate on certain roads where appropriate infrastructure is in place – for example road-markings and road-signs – so that the vehicle can 'read' the road and can know what to do in different situations. Not all roads have road-markings and signs and therefore the Autonomous Vehicle may struggle to cope with these road-types. Therefore, it will either give up and shut down altogether (leaving its occupants stranded), hand control to the driver (thereby defeating the object of vehicle autonomy) or do something entirely unpredictable which could actually be dangerous if not disastrous.

Nevertheless, in the years ahead, CAVs are likely to double up as multi-purpose living spaces where the vehicle occupants will be able to perform many tasks whilst being transported from one place to another. It's possible to imagine situations where cars become 'offices on wheels' in which the occupants can work normally, hold meetings in transit, or even relax and recline during breaks. This will mean that the entire interior space will need to be re-designed to allow these types of activities. In turn, this could mean wider, taller, and overall bigger vehicles which has significant implications for road design.

We live in relatively exciting times in terms of transportation and the concept of vehicle automation is very compelling to many. We just need to be certain that as rapid progress is made, the safety-case for CAVs and the human factors considerations are not overlooked at any stage in the game.

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# HUMAN BODIES,
# DIGITAL DATA AND SOCIAL IMPACTS

# WEARABLES AND SELF-TRACKING: A DESIGN PERSPECTIVE ON PERSONAL DATA

*Pietro Costa*, Luca Casarotto**

## The power of data

The issue of data and the ability to extract actual "value" from it fall squarely within the broad and long-standing topic of the relationship between humans and technology, which involves a number of different disciplines including design.

Sensors and easy connectivity to the network currently produce impressive volumes of data, and nowadays any simple daily action – such as making a phone call, booking a flight, sending an email, or withdrawing cash – is recorded in the form of digital data. There is a rising number of technologies that can generate, archive and process digitized information on people and their daily activities. This "datafication" of humans refers to the utilization of data from people's online activities, app use, embedded sensors in mobile and wearable devices, and physical locations (Lupton, 2021a; Van Dijck, 2014).

It should be considered that this is not a new phenomenon – for example, communication tracking has been possible for decades – but compared to the past, all the issues related to the volume, speed of transmission and variety of data generate consequences that invest the field of privacy, ethics, and individual rights (Boyd & Crawford, 2012), even touching on problems of security and international relationships.

Thus, it is now well-established that everyone's daily life is characterized by interaction with an ever-increasing flow of data, acquired and recorded in large datasets. In this regard, the information philosopher Luciano Floridi defines us as "informational organisms (inforg), mutually connected and embedded in an informational environment (the infosphere), which we share with other informational agents, both natural and artificial, that also process information logically and autonomously" (Floridi, 2014, p. 94).

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Considering the huge amount of personal digital data that is increasingly available, we are now facing a gradual quantitative and qualitative expansion of services for their management, in a system that is in danger of turning out to be more and more data-centric at the expense of an effective view of the data's usefulness for users. The perspective focused on the human person in relation to his or her personal data has been a subject of research for several years and is of particular interest in the discipline of Human-Computer Interaction (HCI). More specifically, an emerging field, defined as "Human-Data Interaction" (Mortier et al., 2014), seems of particular interest. This term, coined in the past few years, reflects exactly upon the centrality of the person in the relationship with personal data. At the root of the research in this specific area, there seems to be the assumption that to gain information or knowledge from data, people need to interact with them instead of merely consuming it passively. Human-Data Interaction should investigate the interaction with data and issues related to its interpretation, but also technical, social, and ethical aspects such as privacy and transparency, as well as the question of how knowledge gained from data can benefit society (Hornung et al., 2015).

## Wearables and digital identities

In the "datafied" society, a significant part of the digital data collected concerns the personal sphere of the individual in his or her daily life. This set of "personal data" consists not only of the data produced by the person but is also shaped by the services or devices that produce data in which the person's identification is contained. Digital identities can involve different aspects of reality related primarily to places, objects, and human bodies. It is precisely in the latter domain that so-called wearable devices have seen exponential growth in recent years, collecting data on daily activities, sports performance, and health monitoring of people. The growing attention to the topic depends on the fact that more and more sophisticated wearable devices with built-in sensors are now available that can record and process data collected during a wide variety of physical activities in real-time. The commercial scale of the phenomenon is remarkable: according to Gartner forecasts, the end-user expense on wearables was $81.5 billion in 2021, with an 18.1% increase from $69 billion in 2020 (Peng et al., 2022).

At present, it is not possible to cover the whole catalog of wearable technologies, because the current market offers an extensive variety, each with its own specific purpose and functionality. The most popular and trendy ones can certainly be identified as bracelets, anklets, wristbands, watches, and small devices that can be inserted into pockets, belts, or hung around the neck. However, even more advanced devices are available today such as hearing aids, electronic tattoos, subcutaneous sensors, head-mounted displays, electronic textiles, and footwear (Nahavandi et al., 2022). These devices are placed on different body parts to measure electrophysiological and biochemical signals and, in general, the information they can record concerns the type of movement made, the number of steps, time taken, spatial area of action, calories burned, kilometers run, weight, goals achieved, and so forth.

The technological ability to collect the various traces of our being in the world makes these devices "as hinges between the body and the network: ways of raising the body's own processes directly to the network, where they can be stored or mined for insight like any other data set" (Greenfield, 2017, p. 33).

In this context, the construction of digital identity from wearables is attractive and of considerable interest, because in this process it is the users themselves who consciously and actively decide to be monitored and to produce data that could be useful to them in some way.

The desire to record data regarding conditions and specific aspects of one's existence is not a recent event. In fact, in the past people used to rely on analogical and mechanical instruments such as diaries, scales, and thermometers to carry out this information collection. With the advent of computer technologies and their increasingly rapid development, this desire to keep track of information related to one's body has grown considerably: "as mobile technology spreads, as electronic sensors become more accurate, portable and affordable, and as analytical software becomes more powerful and nuanced, consumers are offered an ever-expanding array of gadgets equipped to gather real-time information from their bodies and lives, convert this information into electrical signals, and run it through algorithms programmed to discern patterns and inform interventions into future behavior." (Schüll, 2016, p. 3)

Of particular interest in this area, there are the concepts of "self-tracking" and "lifelogging", which can also be defined as a form of self-monitoring of all personal data concerning, for instance, information on one's physical activities and state of health and well-being.

On the phenomenon of self-tracking, a corpus of scientific literature has emerged over the past 10 years that examines it from a social and cultural perspective (Lupton, 2016; Pedersen & Iliadis, 2020). The literature on HCI identifies several types of research related mainly to the analysis of the motivational aspects that support the individual's physical activity-related choices (Francés-Morcillo et al., 2020; Attig & Franke, 2020). Deborah Lupton suggested an interesting way to investigate what the most frequent manifestation of self-tracking is. She identified 5 modes of self-tracking: "private (confined to individuals' consensual and personal objectives), pushed (where the initiative for self-tracking comes from an external agent), communal (which involves sharing personal information with others), imposed (which involves the imposition of self-tracking practices upon individuals by other actors and agencies) and exploited (where people's personal data are used or repurposed for the managerial, research or commercial benefit of others)." (Lupton, 2016, p. 143)

The literature on the adoption and use of commercial tools reveals seven attributes that people consider when approaching tracking tools: data collected, feedback provided, goal-setting capabilities, privacy, social opportunities, style, and convenience (Lee et al., 2021).

In this context, the designer has the difficult task of designing tools that are attractive, appealing, functional from both a physical and digital point of view, and able to give the user a real and reliable data interpretation.

On the hardware level, numerous properties can make a wearable device attractive. For example, in the case of wearables for sport, the proper dimension of the object represents an element of considerable importance: in smartwatches, the product must be of a limited size that does not hinder the user's movements during sporting activity, while also respecting certain standards of visibility and recognition that contribute to making it a must-have and highly trendy item (Greenfield, 2017). Instead, in the digital interface, the most important aspect is the User Experience in relation to his or her data, which once collected are organized to be analyzed through visualization and interaction processes to make them comprehensible. Finally, a correct approach to an effective understanding of data corresponds to a design that integrates several aspects relating to different design areas: from the design of the visual aspect of the collected data to the research of solutions for user involvement, to the adoption of human-system interaction techniques that allow the user to actively relate to his or her personal data. In this regard, it can be stated that the vast majority of personal data monitoring systems share three general functions: to collect behavior and actions, to provide self-monitoring feedback, and to support the user in defining goals (Consolvo et al., 2014).

## Wearables, we have a problem

When wearables started coming onto the market, it seemed that there would be a device to monitor any aspect of daily life. Despite the apparently growing numbers "in recent years [...] a counternarrative has emerged in market research reports and media coverage, in which the failure of wearables to reach predicted markets and to receive long-lasting use has been outlined" (Lupton, 2020, p. 56).

The scientific literature has also highlighted several critical issues, and even with the widespread presence of wearable devices, it has been observed that many people abandon their systematic use after a long or short period. This is calculated to be a rather high percentage: about one-third of users abandon the tracker after a few months (Attig & Franke, 2020).

Considering that these tools are now the most resonant commercial example of the relationship between user and data, it is inevitable that doubts arise concerning their actual usefulness and consequently also regarding how they are designed. In fact, one reason for this abandonment could be found in an approach to design that does not take into account the many variables that could occur when using wearables, with the implicit assumption that both the problem and its solution can be contained within the technological framework. This limitation lies in the belief that user needs can be transformed into quantitative data and resolved by providing other data-driven elements. It may occur that after a certain time a perception may arise in the user that all these numbers are not functional to his needs and are not the solution to his problems. The designer may make choices based on predefined paradigmatic elements that are unlikely to fit the reality and context of the user who will use the device. As a result, the suggested objectives may suffer from a narrow interpretation, with no possibility of further development. For example, a self-tracking system may impose a certain number of daily steps (e.g., the recommended 10,000 steps seem totally arbitrary and not tailored to the specific needs of the user), ignoring the individual's habits, physical situation, family or work commitments, and after the initial motivation, the user may feel at the mercy of data lacking flexibility.

Leading companies, like Fitbit or Apple, have worked hard in recent years to overcome the above-mentioned limitations, proposing systems that allow a certain level of adaptability and more open interpretation of the data collected, through very well-structured work, especially in terms of UI and UX.

Despite this, there are limitations related to unpredictable variables such as possible device malfunctions or user forgetfulness. In fact, it is possible to define self-trackers as "unforgettable" (Follett, 2014), meaning that they must be used constantly and systematically without interruption, which instead can happen for multiple reasons. Any interruption creates an unrecoverable hole in the collected data, and this obviously causes the entire system to lose effectiveness.

Another aspect that makes potential users skeptical of using wearable devices is the issue of privacy: although these monitoring tools may somewhat simplify life, the ever-increasing number of data assemblages that are configured, as well as the constant exchange of data between smart objects, raise important questions regarding technology dependency, security, data privacy, and control of people's information (Lupton, 2016).

On this issue, there are also responsibilities on the part of companies, which usually like to claim that data belongs to people, but at the same time create barriers to accessing and processing data outside the company's closed ecosystem (Epstein et al., 2021). Although there are policies such as the European GDPR that provide the theoretical right to access one's data, the processes can be complicated and time-consuming, with the possibility that non-technical users may be overwhelmed and unable to understand and elaborate collection of their own data. About this, it is necessary to briefly mention the issue of interoperability as one of the topics that will require a great deal of attention from industry and research (Ometov et al., 2021), not only in the area of wearable technologies but also in the practical realization of the Internet of Things concept.

## Evolutionary scenarios for wearable devices

From the above considerations, it emerges that the current generation of wearable devices is still far from perfect. The sensors and technologies developed are increasingly precise and sophisticated, but this does not seem to be enough to unleash the full potential of wearable devices and many challenges still need to be faced.

How can design help to change this trend? Some indications suggest promising ways to identify new opportunities that can shape the evolution of wearables.

As already mentioned, in the design of wearable devices it is essential to work both on the physical components – an aspect that is increasingly influenced by technological characteristics – and on the digital elements, designing the interaction and how the user makes use of the data produced on the device itself and on dedicated software applications. Alongside these two areas, the design of the entire ecosystem is becoming increasingly important from a service design perspective.

From the physical point of view, the design of wearables has seen several transformations over the years. Their functioning is defined by technological components that determine much of their appearance. The miniaturization (Ometov et al., 2021) of technological components has made it possible to increase the number of functions, so for example a smartwatch today monitors more parameters than it did a few years ago while maintaining the same size. This miniaturization of sensors is already driving a design paradigm shift, in which product design will be given secondary consideration and its features will be defined according to the service offered.

A concrete example of this consideration can be found in the recent presentation of contact lenses with integrated AR technology by Mojo Vision[1] at CES 2022 in Las Vegas. In this case, the product is so small that it merges directly with the body, or even disappears in other projects such as smart ingestible pills.

In these cases, it becomes increasingly relevant to consider the hardware component of wearable devices as a "service avatar" rather than a product, where the value comes from the information that the device enables: "When information produces most of the value for users, the hardware and software through which it is experienced takes on a secondary role. Rather than being the center of attention, it becomes a conduit for delivering information driven services. The tool becomes an avatar of the service." (Kuniavsky, 2010, p. 104) From this perspective, working on the content and value that the data generated can bring to people using wearables is still one of the possible ways to make a product truly useful (Zannoni, 2018).

To achieve this, among the strategies often mentioned in the literature for adopting wearables and interacting with personal data there are social influencing and gamification (Consolvo et al., 2014). The former is focused on sharing information about healthy behaviors within social networks or platforms based on the support of an online community of users. The second promotes aspects taken from games, aimed at inducing more appropriate behavior, for example through challenges between users or by offering rewards to reach each goal.

If these concepts are now fully assimilated, there are other ways to build new design spaces and better interaction with personal data, such as the concept of "feeling the data". Through digital self-tracking processes, data is always reduced to visual materializations, in the form of numbers and graphs, encouraging users to think of their information in quantifiable and quantified formats. In this way, privileging the visual aspect closes off other ways of knowing, recording, and understanding personal data: "very few materializations of digital self-tracked data present this information in tangible form, for example. We can see our data, but we cannot usually touch, smell, taste, or hear them." (Lupton, 2021b, p. 193) In various forms, this means that body- and movement-based interactions will play a key role in the new wave of digitalization, moving from the screen to the environment with "faceless" systems (Höök, 2018), where the traditional idea of dialogue between users and systems is no longer present.

In addition to the scientific literature, further indications on the future of wearable devices can be detected through a speculative lens. For instance, in the "Patented Futures" project by the Amsterdam-based Modem studio[2] or in the "Disobedient wearables" project by the French studio Design Friction,[3] the narrative component of critical design fiction is relevant in addressing certain social issues and cultural changes related to data ownership, privacy, persuasive powers of connected devices and informed consent to a constant connection. It is also observable that wearable devices will provide the possibility to expand the boundaries of our physical selves, assuming a general "shift from thinking of individuals as isolated from the 'world' to thinking of them as nodes in a network." (Kunzru, 1997) In this context, it will be interesting to see the evolution of the new social practices of "data activism", in which self-tracking will necessarily have to be "used in ways that go beyond the current focus on individualization, self-optimization and the expropriation and exploitation of people's personal information by second and third parties" (Lupton, 2016, p. 144) to move in new directions that "promote social justice, equality, new forms of agency, political participation, and collective action." (Ruckenstein & Schüll, 2017, p. 272)

## Notes

1 https://www.mojo.vision.
2 https://modemworks.com/research/patented-futures/.
3 http://www.disobedientwearables.com/.

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Habitat interface
RFID for people tracking
habitat

HUMAN-CENTERED TECHNOLOGIES FOR A MORE SENIOR-FRIENDLY SOCIETY

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## Introduction

The increase in life expectancy has globally shown a significant acceleration in recent decades. In developing countries, this is mainly due to a reduction in infant mortality, but a global trend is that of a reduction in mortality in the elderly population, a phenomenon that is particularly noticeable in high-income countries. The global aging of humanity, the change in the quantitative relationship between young and old, is a novelty in the history of mankind which has, and will have more and more in the near future, consequences on the structure and quality of our living environment at the social, economic and cultural level. This evolution in the composition of the population, like any radical change, can have positive or negative consequences depending on the strategy with which we will face it.

The older generations have a wealth of wisdom and experience that represents immense value for the new generations, as long as communication is encouraged. On the other hand, an older population can constitute a burden on the health system which risks becoming unsustainable if current strategies and tools are maintained (Beard et al., 2012). Especially in richer countries, the healthcare system for the elderly is focused on the costly treatment of acute and severe syndromes, rather than on maintaining a healthy lifestyle. It is clear that an increase in the number of patients requiring expensive care in the last few years of their lives can pose a financial risk that is difficult to deal with.

In its 2015 "World report on aging and health", WHO clearly stated that "most of the health problems of older age are the result of chronic diseases. Many of these can be prevented or delayed by engaging in healthy behaviors" (Who, 2015). In other words, if we all led a healthy lifestyle and prevented the conse-

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On the left:
1. Some of the smart objects developed within the HABITAT project.

quences of syndromes, diseases, or risky health states through monitoring and preventive care, not only could we prolong an active and satisfying life even in old age, but we could reduce the impact of the high costs of severe geriatric syndromes on the health system significantly. In the same report, the WHO underlines how the consequences of lifestyle and behavior on the health of the elderly depend only in part on personal choices and are significantly due to the characteristics of the environment and the social system. There is also a cultural obstacle to overcome in order to encourage a change in the behavior and mindset of both the elderly and the people who are candidates to be so: age-related stereotypes.

What are elderly persons, what goals and ambitions can they have, what lifestyle can they lead, and what is, more generally, their potential, are concepts that are affected by an inadequate cultural heritage, matured in very different times from today. In particular, one of the greatest risks is discrimination and generational segregation which greatly limits the possibilities for cooperation, dialogue and social understanding. In this extremely complex and rapidly evolving scenario, in addition to the risk factors listed above, we can fortunately also identify opportunities that can help find both short and long-term strategies and solutions. The digital revolution, together with the expansion of the internet from people to things, continuously proposes new tools or technologies that are suitable or adaptable to the issue of behavioral change. Advanced sensors, wearable devices, pervasive computing, and smart objects allow us to offer different types of monitoring, tutoring, and empowerment services in any place and in a personalized way. It is possible, for a designer or, better, for a team of innovators, to propose personal and environmental systems and services with which to promote autonomy and independence, improve awareness of the health and well-being of one's body, monitor its status as a function of time at different scales, disseminate knowledge on the most advanced systems of preventive health and on the lifestyles recommended for each (Mincolelli et al., 2018).

In this paper we present some projects developed by Quid, the design research unit of the Department of Architecture of the University of Ferrara and of the TekneHub, laboratory of the High Technology Network of the Emilia Romagna Region, in the last five years, which have as their theme the conception of strategies and tools for the empowerment of elderly people through the improvement of the performance of the lived environments and the increase of awareness on lifestyles for behavioral change.

## Methodology

Our design research unit deals with innovating systems of products, services, and environments capable of improving the quality of life by increasing environmental, economic, and social sustainability and inclusiveness (Mincolelli et al., 2020). With this in mind, we have defined a set of constantly evolving methodological tools that can be summarized in the following categories/principles:

1. Human-centered design (HCD) and not only human. At the heart of the project are human society and the improvement of the quality of life. In addition to the traditional HCD approach, which involves the analysis of users and stakeholders of the studied systems, the needs of the stakeholders belonging to the environmental ecosystem and biosphere and those of the artificial intelligence or digital stakeholders that can influence the results are also taken into account.
2. Multidisciplinary approach. In dealing with complex problems, the contribution of very diversified skills and knowledge is necessary. We have developed tools, such as an advanced version of the Quality Function Deployment and specific canvas for collaboration between experts who follow both quantitative and qualitative approaches to research and allow effective collaboration, from the sharing of objectives to the awareness of the development of the project in the different areas, and co-evaluation of the results achieved.
3. Codesign-make it tangible-fail fast. Users and stakeholders are involved from the early stages of the project, even during the analysis of the problem. Interaction is not limited to discussion, designers act as facilitators to allow users and

stakeholders to develop design proposals. The proposals are made understandable to everyone through the continuous creation of prototypes of increasing realisticity, in order to make them fail as soon as possible, without impacting too much on the costs and timing of the project.

4. Technological acceptance-usability. Prototypes are continuously tested in real and simulated environments. The results of the tests determine the survival of the project proposals.
5. Natural interfaces and behavioral change. We are looking for ways of interaction that are easily understandable and do not require an upset of life habits but are capable of suggesting and promoting behaviors and attitudes that improve the quality of life without constraints and without distracting from life itself.

## HABITAT: Home Assistance Basata su Internet of Things per l'Autonomia di Tutti

An innovative application of the previously described methodology was developed by the QUID design research unit in the project HABITAT (Home Assistance Basata su Internet of things per l'Autonomia di Tutti). HABITAT was funded by the Emilia-Romagna Region within the POR 2014-2020 funding campaign, promoting innovative research projects faced by multidisciplinary teams.

The project team was led by CIRI ICT (Interdepartmental Center for Industrial Research specialized in radiofrequency systems) and composed of the following partners: CIRI SDV (Interdepartmental Center for Industrial Research, Health Sciences and Technologies of the University of Bologna, expert in technical validation of inertial sensors), TekneHub (Technopole of the University of Ferrara belonging to the Construction Thematic Platform of the Emilia-Romagna Region high-tech network, working in the field of User Centered Design and Inclusive Design), ASC Insieme (Azienda Servizi per la Cittadinanza of Bologna province) and Romagna Tech (innovation agency of Romagna, competent on dis- semination of results). These institutions were assisted in the smart solutions' prototyping by several companies with significant knowledge in their industrial fields.

HABITAT aimed to develop and test innovative solutions to encourage older people's autonomy, postpone the necessity of personal assistance and improve the quality of life of self-sufficient and non-self-sufficient elderly and people taking care of them. Specifically, common daily products and furniture were enriched with Artificial Intelligence becoming smart objects able to interoperate in a smart open system. These devices can monitor the person's behaviors and habits and autonomously adapt themselves, in real-time, following the user's needs during daily activities in their own environment (Borelli et al., 2019; Mincolelli et al., 2020).

The project followed a HCD approach involving from the beginning different categories of users as elder people, their relatives and caregivers, social and medical operators of community contexts and stakeholders of the healthcare and industrial fields.

During HABITAT were prototype several smart solutions interconnected in a smart platform thanks to IoT:

- A smart armchair integrating sensors in its structure, able to detect incorrect posture, sedentary time and some user's parameters.
- A smart wall lamp working as an indoor localization system thanks to a reader and a wearable tag. This object is able to detect dangerous situations monitoring the user's gait and movements in the house.
- A smart belt integrating inertial sensors and the previously cited wearable tag. This device detects the person's position and postures, reporting any falls or dangerous events.
- A smart wall frame with an integrated touchscreen acting as the user interface of the whole system. This device sends personalized graphical and vocal messages, reminders and alarms to the person suggesting a safe and healthy daily lifestyle.

The design of each device was developed in collaboration with the multidisciplinary research team and with the participation of different typologies of users in specific meetings, participatory activities and co-design workshops. Prototypes were iteratively tested with users for the selection of solutions presenting a high level of accessibility and usability. The final prototypes were tested out of the laboratory context in an apartment specially set up for the implementation of the testing protocol, simulating users' daily routines. The results of the project were officially presented at the international fair Exposanità in Bologna in 2020.

The HABITAT project is characterized by a discrete but innovative use of technology used for the satisfaction of the person's needs. The possibility of personalization, in every context allowing it, significantly implements users' acceptance and the possibility of satisfying peculiar requirements given by a condition of frailty.

## PLEINAIR: Parchi Liberi E Inclusivi in Network per l'Attività Intergenerazionale Ricreativa e fisica

PLEINAIR is the acronym of Free and Inclusive Parks in Networks for Recreational and Physical Intergenerational Activities and is the second interdisciplinary project developed by QUID within the Emilia Romagna's regional grant agreement POR FESR 2014-2020. The project was coordinated by DataRiver and involved the following academic and industrial partners: CIRI SDV, Future Technology Lab, TekneHub, A.I.A.S., Ergotek srl, Sarba spa, and mHealth Technologies srl.

PLEINAIR embraces the concept of the active city (Dorato, 2020) to discourage sedentary lifestyles – caused by different contextual factors such as high urbanization, aging population and misuse of technology (Park et al., 2020) – and reduce its negative health impact on society by developing an enabling built environment that encourages citizens of all ages and capabilities to be physically active in everyday life through equitable access to urban public spaces.

The project proposes the development of an IoMT-based system (Internet of Medical Things) that stimulates citizens to perform physical activity and, hence, to mitigate the impact of aging on their quality of life, by interacting directly with a series of recreative and outdoor fitness furnishings, named Outdoor Smart Objects (Osos), which provide adaptable and personalized experiences according to physical and cognitive characteristics and capabilities of each user.

PLEINAIR aims to foster conviviality and socialization by designing inclusive urban spaces that reduce social berries by fostering an intergenerational environment in which seniors, adults, teenagers and children can share experiences, and activities, build social relationships and enhance communication with each other without any restriction.

Due to Covid-19, PLEINAIR adopted a HCD methodology (Mincolelli et al., 2020) but also speculative design and hybrid co-design techniques to envision and develop the final prototypes engaging with the users both in physical and remote environments (Mincolelli et al., 2021; Mincolelli et al., 2022). The activities involved stakeholders from municipalities, educational institutions and daycare centers.

The final result consists of four OSOs connected to each other through a cloud-based IoT platform and a mobile application, which enable the users to engage with the smart products:

- An interactive floor made up of several smart tiles equipped with sensors and visual feedback that provide interactive games or fitness activities configurable from the mobile application. The smart tiles are the core of the project because they can record the users' performance and elaborate tailored experiences and personalized motivational strategies based on their capabilities and preferences recorded during a specific physical activity.
- An integrated furnishing made up of three smart elements, which are a green unit for monitoring plants, a smart table for playing inclusive cognitive games and a fitness smart bench for physical exercises. The smart tiles embedded in the table and bench provide interactive activities.
- A comfortable swivel chair equipped with a sunshade and a rotating base that guarantees intergenerational socialization, weather protection or privacy depending on its configuration in the environment.
- An ergonomic smart chair made up of a stand assist lift (based under the seat), which is able to recognize fragile citizens and enables them to sit or stand up autonomously.

2. Some of the outdoor smart objects developed during the research activities of the PLEINAIR project.

In the last research phase, the final prototypes were officially installed inside the Museo della Civiltà Contadina, in Bentivoglio (BO), Italy, in which were tested and validated through an iterative and interactive process with the final users. The testing phase lasted two months – from the 23rd of October to the 17th of December 2021 – and involved about 114 users, including children, teenagers, adults, seniors and fragile people. The tests gathered positive feedback from the audience but also many considerations to improve the usability and inclusiveness of the interactive activities, especially those addressed to the elderly.

## PASSO project: Smart sensory cues for older users affected by Parkinson's disease

The PASSO project (PArkinson's Smart Sensory cues for Olders), started as a doctoral research project exploring Human Centered methodologies applied to the field of Inclusive Design addressed to niche users with special requirements. Specifically, this project is addressed to elder users facing the first stages of Parkinson's disease (PD), affecting primarily motor abilities related to maintaining a correct posture and practicing an efficient gait (Meara & Koller, 2000).

The project was developed by Silvia Imbesi, attending the IDAUP Doctoral Program (International Doctorate Architecture and Urban Planning) at the Department of Architecture of the University of Ferrara in Italy, supervised by Professor Giuseppe Mincolelli, in collaboration with engineers of CIRI SDV (Scienze della Vita e Tecnologie per la Salute) of the Department of Electrical, Electronic, and Information Engineering "Guglielmo Marconi" and medical researchers of IRCCS Istituto Scienze Neurologiche, both located in Bologna, Italy.

The design research project regards an innovative mHealth system using biofeedback for the rehabilitation of gait and postural disturbances in persons with PD. Results obtained in the PASSO project are supposed to be used in ambulatory contexts and outside specialized centers to rehabilitate postural and transient gait disturbances and to provide training sessions at home (Imbesi et al., 2021; Imbesi & Mincolelli, 2020).

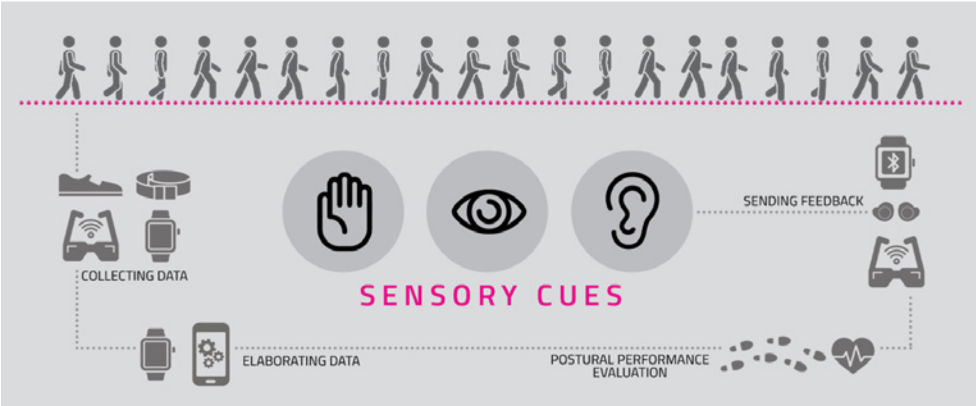
The PASSO project followed an iterative HCD approach: the design process was divided into three main iterative cycles, each one engaging all researchers of the multidisciplinary team. Even different categories of users were involved in the design process to improve the system's usability, accessibility and level of needs satisfaction. The used methodology proved to be effective for multidisciplinary design processes balancing both human and technological factors for the development of smart systems targeted to niche users.

The first design cycle of the PASSO project investigated how visual, auditory, and haptic cues can positively impact on the users' gait. Several sensory cues were tested to understand which typology of stimulation mainly influences users' gait and on which gait spatio-temporal parameters the designed sensory signals mostly impact.

During the second design cycle, a mHealth system based on a wireless body sensor network was developed. This smart wearable system allows the monitoring of trunk postural features and the real-time submission of haptic cues to correct unbalanced postures. Thanks to smartwatches positioned in the shoulders area, haptic cues encourage users to correct their trunk postural behavior, depending on the specific clinical needs.

The third and last design cycle was dedicated to the system interface. The graphic image of the web application managing the system was developed in several versions following the requirements of the different typologies of users involved in the design process. The whole system was tested with users with PD to assess its functionality, usability, ease of use and wearability.

The whole project investigated the relationship between users and wearable objects transmitting biofeedback as prosthesis for the human body, able to improve posture and walking performances. The smart Health system is able to help the person in managing daily tasks properly and autonomously. The methodological approach led to satisfactory results, the project outputs can be considered as relevant in the field of design methodologies for the design of smart devices aiming to improve older users' health and wellbeing.




3. Scheme representing elements of the system.

## Conclusion

The analysis of the three research projects shows that the adoption of HCD methodologies determines the chance of obtaining inclusive and qualitative solutions capable of enhancing older people's quality of life through a multidimensional approach. Indeed, the three projects investigated well-being as a multifaceted phenomenon at different scales and environments, including both the primary purpose of the individuals' care and the social-normative criteria of the subject's person-environment system, which generally refers to happiness, self-contentment, satisfying social relationships and autonomy (Kunzmann et al., 2000).

From that perspective, the research team developed inclusive enabling technologies building resilience among older people by empowering their cognition, functioning, and physical conditions through scalable assistive environments. The final developed solutions aim to foster an active and meaningful life by optimizing participation opportunities in paths of health, safety and socialization, which together are responsible for increasing the quality of physical and mental well-being.

The adopted methods merged the elderly's functional and objective conditions with their intimate and subjective experiences, since their ability to act in the world is equally important to trust and self-esteem, acceptance and wish of sharing personal needs, limits, and abilities (Pollini et al., 2022).

Involving older people in the early stages of the activities helped the projects to raise awareness and acceptance of self-management technologies, building experiences that offer personal care able to maintain independence in daily activities. The HCD methodology involved not only the elderly but also their families and other complementary stakeholders, such as local communities, educational institutions, daycare centers, caregivers, doctors or policymakers, who contributed to face up new social challenges at a systemic scale, building collective solutions and successful projects that embrace the perspectives of a multitude of people.

Lastly, the development of interconnected technologies, such as Artificial Intelligence and Internet of Things, enabled the projects to focus on exploring new values, including, on one side, adaptability and empowerment by developing personalized digital aids, on the other side, autonomy and perceived self-efficacy through lifestyle monitoring. These multidimensional factors were identified through the adoption of a HCD and data-driven approach moving the research activities close to the resourceful aging framework (Giaccardi et al., 2016), aiming at empowering older people to age resourcefully by enhancing health prevention while stimulating and motivating people themselves in improving their everyday lives.

## Notes

The paper was conceived by Giuseppe Mincolelli and written and reviewed jointly by the authors. Giuseppe Mincolelli produced "Introduction" and "Methodology"; Gian Andrea Giacobone produced "PLEINAIR: Parchi Liberi E Inclusivi in Network per l'Attività Intergenerazionale Ricreativa e fisica" and "Conclusion" and Silvia Imbesi produced "HABITAT: Home AssistanceAssistence Basata su Interner of Things per l'Autonomia di Tutti" and "PASSO project: Smart sensory cues for older users affected by Parkinson's disease".

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WEAR AND AWARE: CITIZENS, SENSORS AND DATA TO DESIGN INCLUSIVE RESEARCH PROCESSES

*Margherita Ascari*, Valentina Gianfrate*, Ami Licaj**

## Introduction

The practice of involving citizens or non-expert actors in a research process has become increasingly important in the last decade, both with regard to scientific research activities and in design research processes (Devisch et al., 2018). According to this trend, the practice of Citizen Science (CS) – involving citizens in a scientific research process – has seen an increasing popularity from the academic perspective and increasingly from public institutions such as the European Commission.[1] The European Commission's Green Paper (2014): *Citizen Science for Europe: Towards a better society of responsible citizens and empowered research* forcefully expresses the argument in terms of a paradigm shift towards a more open research process, by emphasizing that "new participatory processes and networking promote the transformation of the scientific system, enabling collective intelligence and the creation of new collaborative knowledge, democratising research and leading to the emergence of new disciplines and connections."

The involvement of citizens in a design research process through participation in conceptualizing, conducting, analysing, interpreting and defining the implications of services and products could be carried out through different means. Those means may require an active involvement of citizens or may be achieved through a passive (and sometimes unconscious) involvement of participants (as, for example, in the case of gathering data through web or social network activities) (Ciuccarelli et al., 2014). In this paper we will focus on processes which actively involve citizens and humans in general that participate in the citizen science processes using wearable devices, with a special focus on urban contexts.

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This paper will address the following questions: How citizen science processes can increase their inclusivity through the segmentation of targets? How could citizens act as activators of data gathering about an urban context using wearable devices? How could devices and sensors be designed in a more effective way?

## From smart citizens to citizen scientists in mutating cities

In the framework of the transformation at urban scale, ecological principles, aspects of social innovation and the adoption of a generative approach have the capacity to become the fertile substrate of new ways of living and producing the city (Gianfrate et al., 2021). Hence the need to generate new strategies that transform urban contexts through resilient processes, which do not always have the same rhythm: periods of gradual change interact with periods of rapid mutations, triggering dynamics that interact across unpredictable temporal and spatial dimensions (Holling & Gunderson, 2002). The COVID-19 health emergency that has affected the global context since the end of 2019 is generating consequences of great transformation on urban contexts and in the dynamics of everyday life, impacting on material and immaterial aspects of society. The pandemic period led to a great increase in the involvement of citizens in the collect data, track disease spread, predict outbreak locations, guide population measures and help in the allocation of healthcare resources to complement official statistics (Segal et al., 2020), contributing to the growth design-led participatory practices and citizen science processes, and in its spreading beyond its traditional domains of ecological and environmental sciences (Wiggins & Wilbanks, 2019; Ascari et al., 2021).

Citizen Science (CS) provides an important contribution to the processes of the democratisation of science, leaded by the involvement of highly diverse participants in research processes, while at the same time strengthening the link between science and society (Irwin, 1995). The diversity of targets addressed by CS declines in specific ways depending on the fields of science in which the participants are interested and the research projects of reference. However recent studies (Raddick et al., 2013; Budhathoki & Haythornthwaite, 2013; Martin, 2017; Lakomý et al., 2020) show that volunteers taking part in Citizen Science projects are mainly male representatives, with a high level of education and with favourable attitudes towards science even before their participation (Füchslin et al., 2019; Curtis, 2018; Haklay, 2018).

Therefore, it is evident the need to understand how to expand participatory channels, tools and methods in order to contribute more effectively to the democratisation process mentioned above (Bonney et al., 2016), avoiding "inequality in participation" (Haklay, 2018) through better targeting of segments to improve the success of recruiting diverse and less conventional audiences. The high potential of Citizen Science in engaging traditionally marginalised communities in data collection and advocacy in the context of environmental and social justice (Coburn & Gormally, 2020) is further strengthened when put into the smart city context, where training and education is a key element for understanding, accepting and using new enabling technologies. Innovation and development in the technological sphere have enabled the large-scale dissemination of such tecnologies, through digital or physical and tangible interfaces, which have fully entered into the practices of governance, management and performance of activities and services within cities (Newman et al., 2012).

As the great potential for the application of these technologies emerged, cities began to absorb these new tools, through a technocratic approach: the initial vision related to smart cities envisaged the widespread use of digital systems mainly related to surveillance and control, integrating virtual realities, management platforms, with great promise on the "intelligence" of cities. The tecno-centric perspective (technological and digital means were considered as a multiple entity able to solve urban and global challenges) was not able to take into consideration the active involvement of citizens, but was mainly based on the relationship between public institutions, research and private entities, in parallel with triple-helix model of knowledge transfer and innovation (Etzkowitz & Leydesdorff, 1995). Shortly after its beginnings, this model appeared to be very focused on aspects of infrastructure and not very adherent instead to the real capability of institutions, businesses and citizens, demonstrating the limited capacity to include the instances necessary to improve the lives of citizens, because it was disconnected from the real problems, and incapable of placing citizens at the centre of the development process (Bria & Morozov, 2018).

The increasing popularity of CS has a relation with digitization and the diffusion of digital media. In particular, digitization has been, on one hand a catalyst for the diffusion of digital means that has enabled new possibilities regarding crowdsourcing and participatory research in general, and on the other it opened new questions regarding the reliability of crowdsourced data and methods (Dickel & Franzen, 2016).

The JRC report (Craglia & Granell Canut, 2014) shows the limited synergy between CS initiatives and the operationalization of smart cities, due to the lack of interoperability and reusability of the data, apps and services developed in each project, with a difficulty in comparing the results of CS and Smart Cities and Communities projects with a limited transferability from one context to another. In some cases, this is determined by the ephemeral nature of many of the data, which disappear shortly after the end of the projects, the lack of reproducibility of the results and the difficulty of longitudinal time series analyses. The great challenge thus appears to be, on the one hand, to define and integrate the analytical methods required to integrate quantitative and qualitative data from heterogeneous sources in a new way, which requires cross-sectorial research, and on the other hand, to build and maintain the trust of participants in any Citizen Science or Smart City project, engaging community as agent and not only assuming the community as a research object. Involving people in data gathering and research could also be seen as a way to contrast data gap and, therefore, social exclusion. Recent studies show the relation between data gap and the observation of urban phenomena, for example with regard to gender-gap and intersectional practices (Criado Perez, 2019; D'Ignazio & Klein, 2020). Generally, high resolution and gender-disaggregated data about population are rarely available, leading to the misinterpretation or biased-interpretation of gender-related phenomena and to an inequality in accessing to data and digital technologies (Data2x, 2021).

The effects of gender data gap in cities and territories are represented by the work of GeoChicas, an initiative and a collective aimed at reducing gender data gap through the use of Open Street Map (OSM). The initiative started from the recognition of a lack of diversity in the user/editors of OSM, which were mainly male representatives (Gonzalez, 2021). Among other projects, their work uses crowdsourcing to map phenomena that are not recognized in official data, such as the map of Feminicide in Nicaragua[2] or Maps of gender gap[3] in the naming of streets in different cities all over the globe.

The exacerbation of social exclusion through digital systems and data could also be related to aspects other than gender. This is the case of the action taken in the city of Boston to solve the problem of potholes in the streets. The use of an App on the citizens' device to have a mapping of the potholed streets excluded people with low-income that could not access to adequate smarphones that were needed fot the mapping, leading to a lack of potholes mapping and resolutions in specific areas of the city (Hand, 2022). The lack in democratic access to technologies, and then to online activities by marginalized groups also leads to producing less data and to be invisible in public projects or policy making processes (Giest & Samuels, 2020). Hand (2022) call this aspect of data-gap Dark Data, using a metaphore related to the dark matter, which exists but has never been recorded even if it could have important effects on public conclusions, decisions and actions.

To reduce these negative effects, inclusive Citizen Science processes could reduce social inequalities in cities through a more responsible production and use of data and digital systems. The increasing development of Citizen Science associations in Europe and the United States, as well as forums for smart cities to share experiences, components and tools, are moving in this direction: examples of mapping, Citizen Science and DIY science show how a reconfiguration of technology, capable of increasing its social role, is possible to make the Smart City socially meaningful. Citizen Science and its public engagement process thus become key also in technology co-design, to discuss data collection protocols or understand the analysis, nurturing new and existing links between individuals and communities, overcoming the top-down and technocentric approach that tends to ignore what is happening on the ground in an exclusive logic of efficiency and productivity that usually characterizes the Smart City. As pointed out by Wolff et al. (2015), in order for the bottom-up approach to become a reality, citizens must possess the necessary skills to acquire, interpret and exploit urban data that are constantly increasing in quantity and complexity.

## CS as an interface between humans and the environment: wearable sensors as (un)inclusive activators

Considering Citizen Science as an interface between humans and non-humans allows us to examine which elements act as activators or mediators in the exchange of knowledge between these two realities. In the past few years, the progressive miniaturisation of digital systems has made them ubiquitous, i.e. spread throughout space, and pervasive, i.e. able to spread into previously unexplored fields (Pellegrino, 2006). This spreading of digital systems has oriented the debate in design discipline to, on one hand, the novel risks, related for example to digital surveillance (Bianchini & Morozumi, 2021), and, on the other, to novel possibilities related to the integration of bodies and digital systems. In fact, diffuse sensors infrastructure share with humans the fact of both being “experiencing subjects” (Gabrys, 2019). Those sensors, in particular when they are integrated in wearable devices, are able to enhance human sensitive experience, thanks to their ability to provide observations that are more precise than those provided by human bodies. Moreover, those sensors are able to produce outputs of the observations in interoperable formats (data), which are potentially comprehensible by other subjects (humans) or other objects (digital machines).

Within this paper, systems equipped with sensors are to be considered as “activators” of a CS project as they enable humans to become more active in a process of understanding the environment.

The main focus of our study is on the systems equipped with sensors that are also wearable. Wearable devices with those characteristics are only a part of possible "activators" – other activators, for example, are the desktop DIY kits for environmental monitoring, which enable the construction of a diffuse monitoring infrastructure through the installation of desktop systems on houses or public and private buildings (Gabrys, 2019). Those systems, in general, allow citizens to have an active role in monitoring a phenomenon, which can lead to the construction of policy guidelines for cities and territories, constituting, under certain conditions, activators of an eco-political involvement of citizens.

The main difference between a desktop system and a wearable one is related to the fact that wearable systems, as well as acting as tools for observing the context, are usually able to take measurements on the human body which is using it, creating a relation between the body and the environment. This capacity opens up one of the limitations we intend to investigate with respect to such devices, which is the poor adaptability they have with respect to female and|or non-conforming bodies. Such disparity is related to different aspects:

- The pre-definition of comparison parameters related to the body (e.g. vital signs) which are mainly based on standard-considered bodies – generally male and white (Grigliè & Romeo, 2021; Criado Perez, 2020).
- The exclusion of qualitative data related to human perceptions, which may constitute a key element to address sustainable behavioural and mindset changes.
- The intersection between different socio-economic-cultural variables (such as age, income, education, ethnicity, gender, sexual orientation) that can influence people's capacity to use and interact with data and devices.
- Design aspects, related to usability and affordance, of wearable products that do not take into account the necessity of adaptation with regard to non-conforming bodies (Maragiannis & Ashford, 2019; Zannoni, 2018).
- Lack of feedback and limited accessibility and understanding of data elaboration deriving from the data gathering.

All these considerations are the result of preliminary research carried out within the ReSET project Restarting the Economy in

Support of the Environment through Technology – which aims to enhance the adoption of environmental intelligence – i.e. coupling monitoring and modelling – to co-design and co-implement green investments for urban adaptation to climate change and resilience. A first critical review of the available sensing devices let emerge that wearable systems equipped with sensors may be considered, on one hand, a resource as they act as activators for collective monitoring which is able to produce data that cannot be produced by a single subject or object, giving a more complete understanding of environmental processes (Chan et al., 2021) but, on the other, if they are inaccessible, unusable or inadequate with regard to specific targets or groups, those systems may be harmful as they may aggravate marginalization phenomena.

## Data gathering and data communication/visualization in RESET CS process

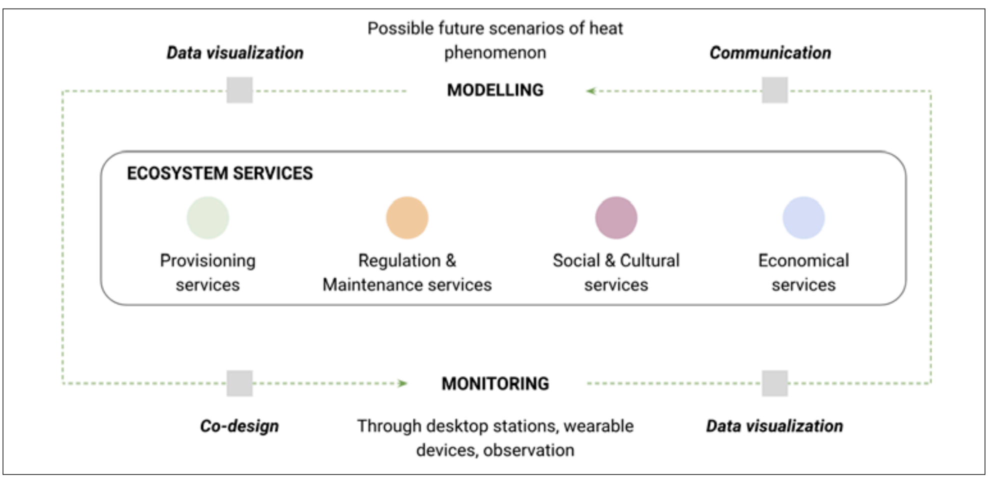
The Advanced Design Unit-University of Bologna together with the National Research Council of Italy (CNR), in the frame of the EC H2020 ReSET project (Mulligan et al., 2021), is engaged in the definition of community driven and co-design activities related to the improvement of existing green areas in order to enhance the production of ecosystem services, in particular related to adaptation to heat phenomenon and socio-cultural services. The activities will implement a collaborative monitoring phase, based on the installation of FreeStation desktop climate stations (fig. 1) and crowdsourcing data gathering through wearable devices (for quantitative data) (fig. 2) and observation activities (for perceptions and qualitative data) (fig. 3). The Citizen Science initiative will adopt feedback tools based on data visualization and multiple data sharing (e.g. machine-readable raw data, data visualization artifacts with different levels of complexity), also aiming at improving data literacy in non-technical participants (fig. 4). The expected outputs are co-designed indication for the improvement of public existing green areas and indication for the inclusive improvement, from a usability perspective, of desktop climate stations and wearable devices.

1. FreeStations are low-cost and low-maintenance solar powered climate stations that could be provided with different sensors and actuators for high-definition environmental modelling. Some stations will be installed in Bologna for heat monitoring.


2. FreeStations walkables/wearable devices are battery powered and are provided of different sensors and actuators for Air quality monitoring and heat monitoring. In Bologna, the wearables will be used for monitoring and will be tested also from a usability perspective.

3. Observation activity in green areas with students.

4. Schematic representation of the Citizen Science process that will be carried out in Bologna in the frame of RESET project.



## Conclusions and future research

Following the introduction of the concept of Anthropocene, the role of human actors has seen a change of perspective related to the need to find novel solutions and form of participations able to reduce the human impact on climate change, and in general to reframe the relationships between humans and nature (Berkhout, 2014). Moreover, the evolution of the triple-helix model in the quadruple-helix, that included citizens and civic society, was followed by the introduction of new models for European smart cities, which included and recognized the importance of experimentations and citizens' participation – as in the case of Living labs – also in the co-definition of urban development strategies (Concilio & Rizzo, 2016).

Nowadays, the urge to deal with urban context which is mutating from different perspectives (e.g. ecological, digital, societal) lead to the necessity to consider, along with humans, the environment as an active element in development processes of the city, as defined in the quintuple-helix model (Carayannis et al., 2012) and to produce city models that are meaningful for each actor and inhabitant (D'Ignazio et al., 2019). In this perspective, CS projects may be considered as an interface able to connect the environmental dimension with the human dimension, able to activate an exchange of knowledge between these two realms.

Starting from these assumptions, ADU is designing and carrying out a prototypal phase to activate an inclusive citizen science process connected to the Bologna ecosystem services, coupled to the definition and use of data viz as community-awareness tools.

ReSET low-cost wearable devices will be collectively tested and analyzed to let emerge the criticalities connected to their adaptability to different users, considering an intersectional perspective (considering the interrelation between different socio-cultural aspects such as gender, age, ethnicity, income, etc.).

At the same time the ADU unit will couple the community-based initiatives (workshops, crowd-sourced data gathering, CS walkings) with:

i) Data viz experimentations, deepening frontier innovations, such as Big data in small Viz i.e., a study that seeks to understand how devices can be used as a direct information carrier for the citizen involved, having to take into account the as-yet unexplored issue on the representation of large amounts of data in very small spaces or screens such as those of any smartwatch (Parnow, 2015; Pronzati, 2021).

ii) The capacity to measure and consider aspects more related to people's perceptions as key data for a more inclusive interpretation (Licaj, 2017) that opposes the mere extractive/analytical approach to data, but advocates for the circularity of knowledge that moves through the citizen, comes to Academia and back to the citizen, in a cyclical interchange. ADU will take inspiration from existing data-driven design experimentation, such as the artwork recently exhibited at MAXXI *Data Meditation* by the italian collective HER She Loves Data in 2021:[4] people and participants have been engaged in a dialogue with the algorithm that asks questions about their perception of the space they are in, then returns the outputs of the collected data in the form of sounds, providing an inclusive and multisensory experience where the participant feels part of the process.

The mix-matching of these research branches positions CS and its tools at the center of a cross-fertilized system of investigation, that can feed design education, research and production in a shared culture of responsibility.

**Notes**

[1] (https://ec.europa.eu/jrc/communities/en/community/citizensdata)
[2] https://seleneyang.carto.com/builder/14f3a6a1-03ce-47df-b3e7-bf1bd7b36298/embed.
[3] https://github.com/geochicasosm/lascallesdelasmujeres/blob/master/README.en.md.
[4] https://data2x.org/wp-content/uploads/2021/03/Landscape-of-Big-Data-and-Gender_3.5_FINAL.pdf.

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This book was born from the Human Body Interaction research begun in 2020 and performed by the Advanced Design Unit at the Department of Architecture of the Alma Mater Studiorum - University of Bologna in a partnership with the company RE:Lab. The research investigates how the pervasive spread of new technology creates an unprecedented awareness that takes shape in deep body manipulation practices and processes through design. This research has been the result of three years of scientific reflection that has contributed to developing research on contemporary design transformations and how such new design methods are finding a deep exchange with the human as a whole – mind and body.

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