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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 multilayer 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.

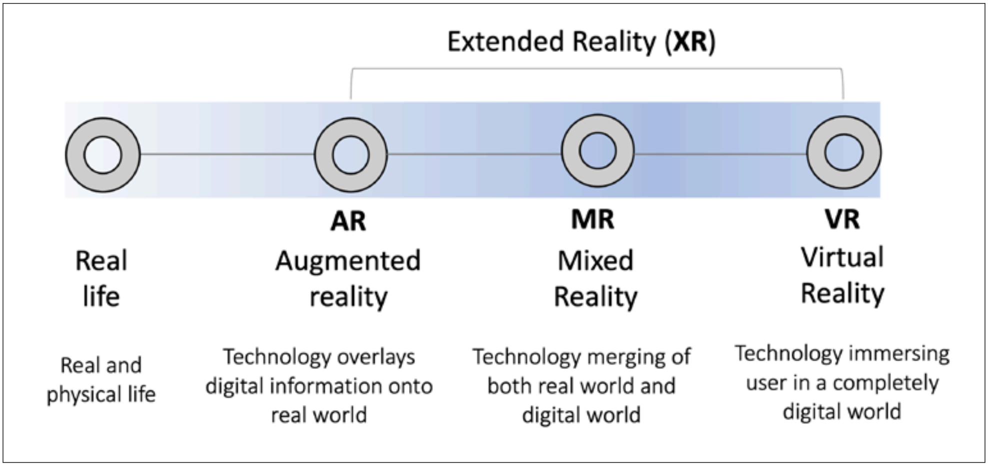
Figure 2 shows a potential segmentation of the technologies that define the VR-AR market; from it, we can see that the XR technology value chain is particularly complex and can be split into many subsets, and that there is a wide array of fields of applications, spanning the sectors of industry, entertainment, 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.

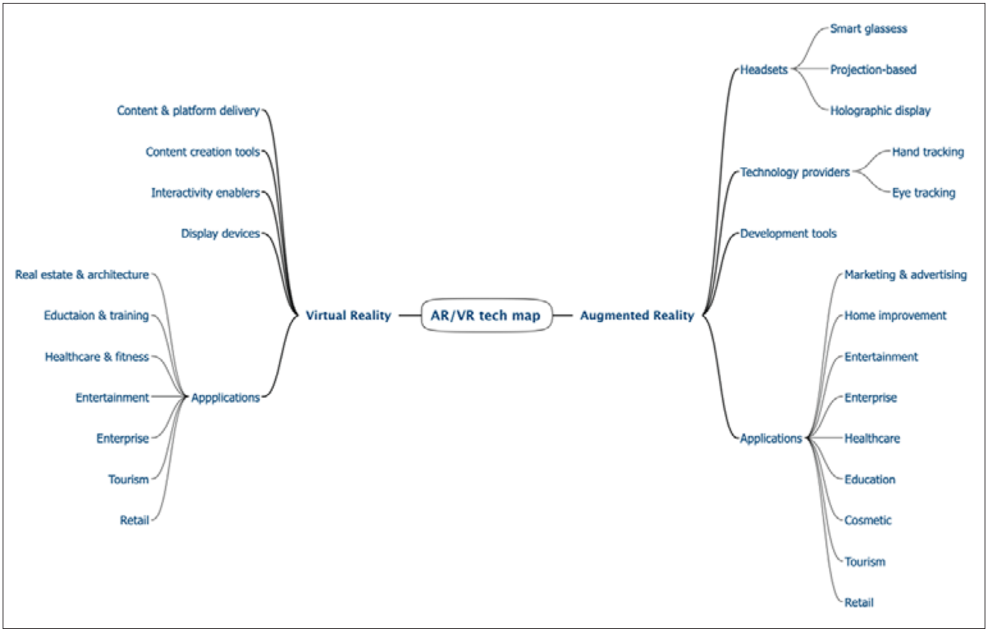
What makes XR technology interesting is the place it is assuming within the fourth industrial revolution (Schwab, 2016), where it is modifying user interfaces, and the next step will be a shift from touch screens to computer-generated images that can be touched and felt through atypical techniques; so, 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, 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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