FORESIGHT ON DEMAND

Foresight towards the 2nd Strategic Plan for Horizon Europe

Transhumanist revolutions deep dive

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Scope

The twelve scenarios presented in this document are part of a foresight project aimed at helping prepare the *2nd Strategic Plan 2024-2027* of the *Horizon Europe Framework Programme for Research & Innovation*. The project was conducted by *Foresight on Demand* Consortium on behalf of the *European Commission*'s *Directorate-General for Research and Innovation (DG RTD)*.

The scenarios are informed by transhumanism, portraying futures in which the human condition - our bodies, functions, and lives – and the features of societies are fundamentally transformed by technology. Even though scenarios are built along the lines of particular scientific and/or technological advancements, the discussion spreads over sociotechnical ensembles and the re-conceptualization of the relationship between technology and society by 2040.

The work leading to this report started with a horizon scanning exercise to identify a series of technological innovations and scientific breakthroughs that may be considered key factors towards re-engineering human nature. In parallel, the authors explored diverse narratives regarding the human condition and significance in the world, dreams and fears embodied in the so-called collective imaginary, echoing through myths and fantasies to literature, cinematography and the wider culture. At the intersection of these explorations, twelve topics were selected and further expanded into scenarios. They are not intended to cover the full spectrum of themes regarding human enhancement, but present a relevant 'sample' of potential future trajectories.

We propose these narratives as *exploratory scenarios,* describing futures where both positive and negative consequences are palpable. They are *not normative,* outlining a vision of the future deemed desirable. We invite readers to regard them as devices for *imagining* the future and *debating* the future. They aim to nurture a reflection on the dynamics of change, future opportunities and potential threats, and in doing so they contribute to future preparedness.

Regarding deep technology, there is often not a unique and complete understanding of phenomena, knowledge uncertainties abound. Latour (1987) refers to this as 'science in the making', where knowledge is actually socially constructed in the middle of the controversies generated by uncertainties. This is different from 'ready-made science', where knowledge is stabilized and there are no major controversies. The technologies involved in these scenarios - brain-machine interaction, sensory and brain stimulation, digital twin of the brain, molecular therapies for delaying aging, to name just a few - are surrounded by uncertainties and unsettled debates, including on the meaning of attributes such as 'efficient', 'safe', 'accessible', 'ethical'. Thus, the scenarios present an opportunity for scientists, engineers, ethicists, regulators, but also the wider public, to engage in a conversation about how emerging technologies can mature for the benefit of humanity, even without a full understanding and predictability of causal effects. In doing so, they will reflect on what we are as humans and what kind of humans we could or should become.

Three types of scenarios were developed:

The first type describe futures where scientific and technological advancements **enhance embodied experiences**: *Sensory augmentation:* extending human senses beyond the natural limits and adding sensorial modalities which are not native to humans. *Sensory and brain stimulation, psychedelic microdosing:* inducing altered states of consciousness, for healing purposes or for fostering new perspectives on being human. *Molecular therapies* for delaying aging; and new *artificial reproductive* technologies allowing people to be fertile until much older age.

The second type explore futures where human capabilities are **extended by embodying non-biological means**: a significant share of elderly people using *exoskeletons* for prolonging active life, for maintaining their mobility or as a form of assisted living; *brain-computer interfaces* leveraged in semi-automatized work environments, to improve learning outcomes, and to control smart devices; *Brain to brain communication* supporting cognitive and emotion sharing, leading to the creation of 'hive minds' covering multiple aspects of life.

The third type focus on the **simulation and replication of the human body and mind**. *Digital body twins* allowing alert signals for disease prevention and the simulation of the short- and long-term effects of a person's behavior on their health and body; *Digital twins of the brain* allowing testing hypotheses in cognitive science, in mental health studies, responses to different types of treatments; *Digital immersive worlds* – gaming/ fantasy worlds or 'mirror worlds' that are replicating real-life environments – hosting interactions among people and automated entities; *Digital replicas of the deceased* changing the socio-political understanding of grief; and *Artificial agents* with complex underlying computational procedures (including e.g. self-reflection, development of value system, affective computing) and sophisticated interfaces calling for new theoretical frameworks of consciousness.

Each scenario is broadly organized along three main parts:

- *The future scenario* - a brief summary (in bold) that paints in broad strokes the transformation in 2040, together with "the bigger picture", a section that describes the implications of this transformation on society (e.g. impact and tensions), sometimes including 'imaginary heroes' who live in that world.
- *The present* - current signals pointing to the respective scenario, meaning present conditions of technology, social practices and structural drives that suggest the possible development of such scenario. It's worth noting that while we discuss current

signals that might indicate the emergence of a scenario, we make no estimate on the likelihood of those applications actually being realized in the future.

- *Implications for R&I* – a brief section highlighting a number of topics where R&I is needed, e.g. to advance technological progress, to understand and qualify potential risks, to advance the understanding of the socio-economic implications of such innovations.

Finally, we note that while we propose twelve distinct scenarios, the boundaries between them are neither well defined nor rigid. The converging technologies invoked in these scenarios (nanotechnology, biotechnology, information technology, and cognitive science - NBIC) often overlap and impact each other. As a consequence, some of the scenarios are also overlapping, with synergistic effects and complementarities between them.

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Acknowledgements

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Moreover, in October 2022, another workshop brought together policy experts who discussed, among other deep dives and case studies, the links between a number of these scenarios and the impact areas from the Horizon Europe First Strategic Plan.

Finally, we express our gratitude to Nikolaos Kastrinos from DG RTD, whose detailed feedback and thought-provoking questions helped consolidate the scenarios.

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The images accompanying the twelve scenarios were generated using the DALL·E 2 – OpenAI platform.

Enhancing embodied experiences

Design your senses

Main drivers: Sensory augmentation

By 2040, people working in particular fields will be able to perceive sensorial stimuli which are not native to humans, such as magnetic field, flow, pressure, infrared sounds etc., in a way which will be as effortless as using their natural senses.

The bigger picture

A ‘revolution’ of senses will entail sensory augmentation devices that achieve fast and genuinely perceptual experiences. Such devices will extend human senses significantly above the natural limits (e.g. ultrasonic hearing, hyperspectral vision), or add sensory modalities (e.g. animal senses such as echolocation, magnetoreception), or use an existing sense to convey new information.

It will be possible to augment people for tasks and activities where very detailed and enhanced perception of the environment makes them more effective: monitoring, surveillance, search and rescue, manufacturing and handicraft where an eye for detail (in a multimodal sense) makes a difference (e.g. designing soundscapes or fine cuisine). Clearly, these technologies will also be useful in the military and may present advantages in combat, reconnaissance and scouting.

For example, an enhanced rescue worker responsible for search and rescue of missing persons will be sensorially augmented to hear weak sounds, and will have an extremely enhanced sense of smell (more sensitive than that of a dog). She will perceive infrared signals. She will also have a sense of a magnetic field which will make it easy for her to orient herself even in complete darkness [1]. She will therefore be able to easily detect victims who have got lost in a forest or in the mountains or are trapped in collapsed buildings. Her working hours will be, however, limited, as after missions she will get a heavy sensorial overload and will experience a decrease in cognitive capabilities. Therefore, she will be constantly monitored and tested to detect signs of fatigue and decline of performance and to give her sufficient time to recover.

It is not clear what the toll of sensorial augmentation will be on the human body. Sensorial fatigue and enhanced sensorial sensitivity are problems known to be experienced even by many non-enhanced people.

Moreover, if augmented sensory capacity becomes normative in a particular field of work, it might pressure other people to undergo similar enhancements in order to compete.

Current signals pointing to this scenario

Sensory enhancement has been around at least since the invention of magnifying glass, hearing aids, seeing aids, night vision goggles - they all enhance the sensorial capabilities of humans and are used regularly. These are add-on devices, clearly separable from the wearer. Cochlear implants and retinal implants are as well proven to be useful in compensating for the loss of hearing or sight. There are also devices that complement natural sensor modalities (e.g. wearable belts that through touch sense point to magnetic north) and others that allow using an existing sense to convey new information (e.g. tactile perception of a speech, ‘hearing’ in color [2]).

Developing devices/implants that significantly enhance human senses (e.g. ultrasonic hearing, hyperspectral vision) or add non-human sensory modalities (e.g. echolocation) is challenging, as connecting them to the human peripheral nervous system is not currently a well-studied or solved problem. However, experiences with patients losing sensorial capabilities and being forced to replace them with others (e.g. blind people using echolocation instead of vision) points to the fact that the brain is very plastic and can fuse information from new sources [3].

Implications for R&I

- Brain science: Improving invasive and non-invasive brain stimulation; Understanding how new senses construct new neural pathways to the brain.
- Investigating implications/risks related to biohacker communities.
- Expanding the field of sensory studies: e.g. Bodily ways of knowing, Novel forms of sensory perception leading to new practices and modes of expression; The intertwining of sensory ordering and social ordering; The role of social institutions in changing the "distribution of the sensible".

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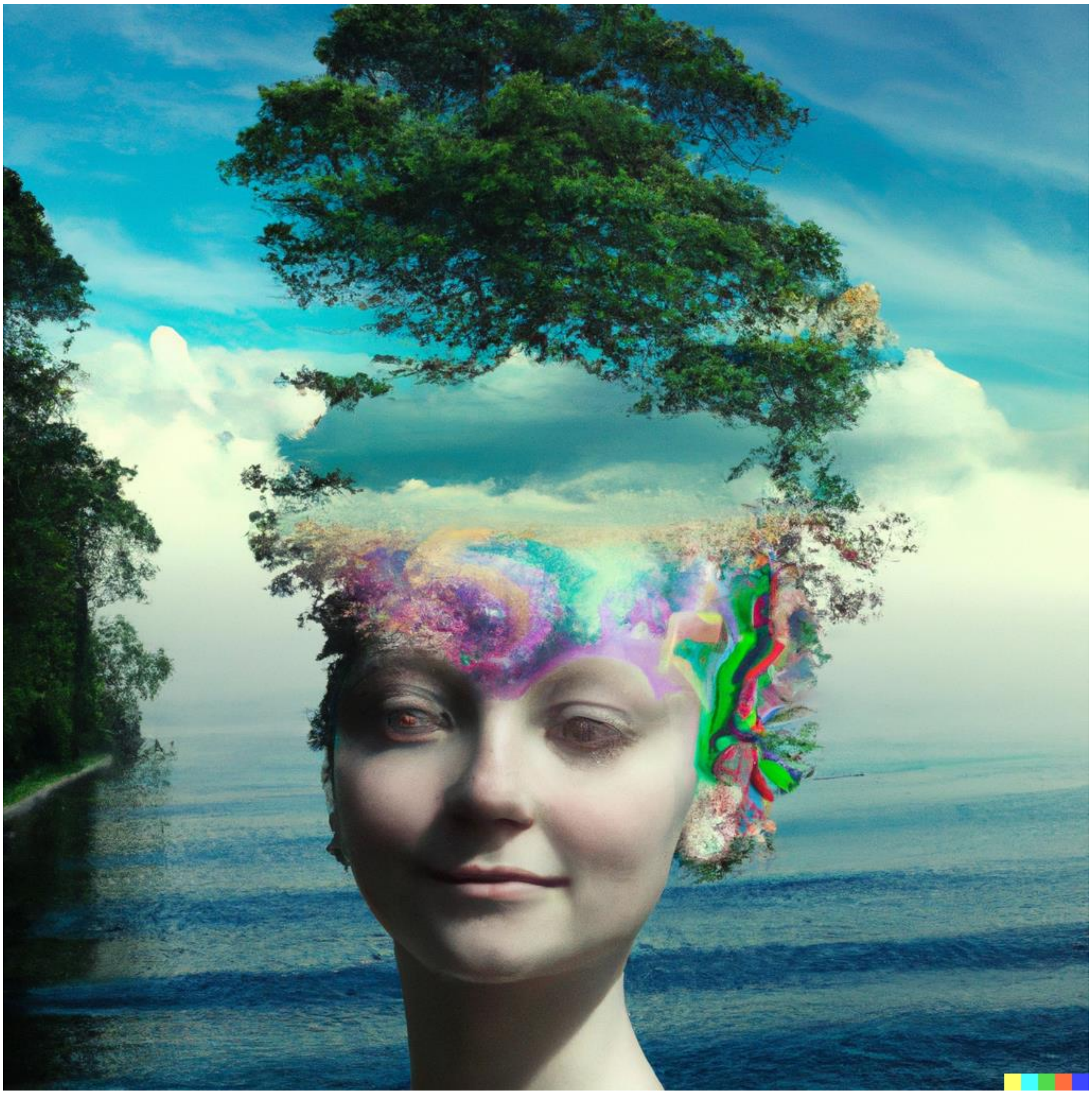
New windows towards inner space

Main drivers: Psychedelic clinical trials, sensory and brain stimulation, consciousness research.

By 2040, a combination of psychedelic microdosing, sensory and brain stimulation will have been integrated in a consciousness alteration cabin which will be profusely and effectively used in psychotherapy for healing e.g. post-traumatic stress disorder, for personal growth processes, for fostering new perspectives regarding our relation with nature or even for entertainment.



The bigger picture

Consciousness alteration therapies will curb the suffering of millions of people diagnosed with psychological disorders. In addition, they will have the potential to radically change the social landscape, fostering interpersonal bonding and feelings of closeness. They may also contribute to better decision making and creativity enhancement. The transformative experiences they generate reveal something otherwise unknowable, and will change people in some fundamental way, giving them powerful new perspectives on their place in the world and within nature. Tensions in this new world concern potential manipulation of effect, misuse.

Current signals pointing to this scenario

Studies of microdosing psychedelics in different mental health applications are increasing [1],[2]. While research programs are arduous due to regulatory obstacles, results of the first ever, late-stage clinical trial for a psychedelic showed a major benefit for PTSD patients, paving the way for potential FDA approval [3]. Anticipating a renaissance of psychedelics, investment is pouring in companies related to the development or the administration of psychedelic-like drugs in the USA. Not only economic investment, but an intellectual one is leading major medicine universities in the USA like University of California San Francisco (UCSF) [4], Harvard [5] or Yale [6] to open research programs on psychedelics. These are capturing European talent that encounter too many difficulties in Europe in conducting similar research.

On a different track, dedicated literature and technology-supported experiments explore the transformative potential of dreaming. Hence, a special issue of the journal Consciousness and Cognition proposes adapting Human-Computer Interaction (HCI) approaches to dream engineering; it discusses a set of technologies to influence sleep for memory enhancement, creativity, emotion regulation and physical rehabilitation [7]. It’s unclear if it is necessary to control content during consciousness alteration, and, if so, how to achieve it. Indeed, some types of therapies like the Eye Movement Desensitization and Reprocessing [8] or Holotropic Breathwork make use of dream-like states induced by voluntary eye-movements, respectively rapid breathing in the healing of traumas. Moreover, lucid dreaming has been previously associated with increased creativity [9]. This induction of self-awareness in dreams (i.e. lucid dreaming) has been achieved through brain electrical stimulation [10]. All these developments seem to offer a reinterpretation and new tools for addressing dreams in psychotherapy. On a more popular facet, it is worth mentioning Dreammachine [11], an installation in the UK which is using sensory stimulation to generate dream-like experiences, which offers the general public the possibility to experiment in this context.

Implications for R&I

- Need to reduce regulatory obstacles for psychedelics research. A recent review [12] of psychedelic research underscores challenges facing studies that seek to discover both micro- or high-dose effects of a psychedelic drug: few large randomized trials have been done in humans. Moreover, there is a need to define a clear methodology enabling conducting Randomized Control Trials with psychedelics.

- Multi-disciplinary psychedelics and brain stimulation research to understand more about the nature of the human mind and consciousness, taking into account anthropology (incl. Indigenous knowledge), neuroengineering, phenomenology and neurosciences.
- Neuroethics of sensory and brain stimulation techniques, dream engineering and sleep manipulation is critical; evaluating the potential misuses of dream engineering technology.
- Creativity requires a research framework for systematic study.
- Developing a methodological approach for First Person Science

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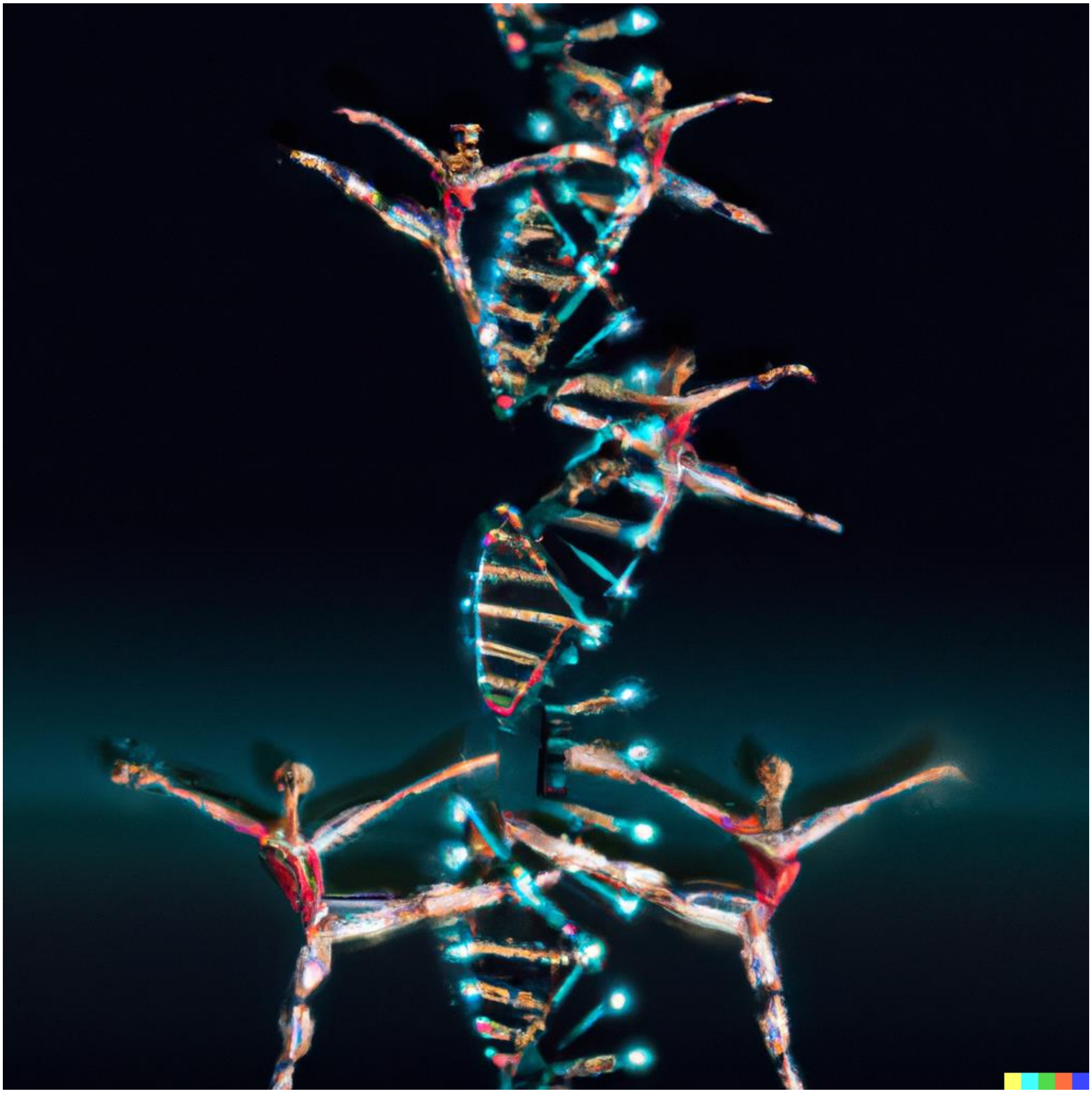
Extra twinkles in the wrinkles

Main drivers: molecular therapies for delaying aging and diseases of aging

By 2040, there will be people seeking increased longevity by accessing telomerase gene therapy. This will effectively protect the telomere-treated humans from age-related diseases and will increase their longevity. This and/or other age-retardation techniques will change the lives of individuals and the fabric of societies.



The bigger picture

One of the molecular pathways of aging is the shortening of telomeres, the protective structures capping the ends of chromosomes. Telomeres grow shorter each time a cell divides, and when the structures reach a critical length, cells either stop dividing or perish. Telomerase gene therapy is intended to lengthen patients' telomeres in order to offset cellular aging.

A possible scenario is that telomerase activation therapy will be first used to treat patients with degenerative pathologies and then this will be extended to healthy individuals to prevent the appearance of these diseases and to have an increased health span and life span. The cost of manufacturing will remain prohibitive for some time, making it a niche therapy for the financially privileged. Disruptive advances in cost and efficiency will be needed in order for telomerase gene therapy treatment to enter mass market. Until then, access to the telomerase activation therapy or other techniques for delay aging may generate two types of citizens, people with financial means that postpone aging and remain healthier, and others that age and suffer more from diseases. Therefore, life-extending technologies may broaden existing divides between more versus less affluent societies or create new divides (e.g. between countries with less/more restrictive regulatory, ethical or religious barriers).

A substantial increase in lifespan – e.g from 80 to 120 - would open up new possibilities and freedoms. People would have more time in the course of their lives to enjoy and deepen familiar and new experiences, to complete more life projects, to capitalize their gained experience and wisdom in multiple careers, to dare give themselves multiple chances at things they deem important. Moreover, if the prospect of dying will be much delayed, the fear and anxiety related to one’s death might diminish, alleviating many of the distortions this fear can generate in people’s lives. It’s also possible (but certainly not guaranteed) that living longer lives could nurture a different relationship of humans to the planet. It might change people’s worldview, prompting them to embrace long-term thinking and sustainability.

It’s unclear whether such therapies would mean aging is slowed more or less equally at all stages of life, or if the healthy years of the prime of life are greatly extended, or if bodily degradation and decline come abruptly after many years of good health, followed by a sudden death. Each of these variants calls for a discussion on the quality of life of those with extended lives, because even in the absence of certain age-related diseases and disabilities, human capabilities, such as mobility, memory, cognition, sensory acuity, and communication decline dramatically with age.

Moreover, if lifespans lengthen drastically, the growing elderly populations and the need of society to accommodate them might also bring forth the senescence of society at large, a stiffening of social pathways, an inflexibility of worldviews and institutions, less welcoming of the uninitiated youth.

Current signals pointing to this scenario

A telomerase gene therapy which is able to maintain telomeres longer was developed and proved able to extend the life of mice without increasing cancer risks [1], [2]. Telomerase activation has been also shown to be effective in mouse models of different degenerative diseases, such as heart infarct, pulmonary and kidney fibrosis, aplastic anemia etc.

A 2015 study from Stanford [3] prompted similar effects in isolated human skin and muscle cells; the treatment lengthened cells' telomeres by fiddling with RNA, which helps cells build proteins. The treated cells didn't go on to divide indefinitely, which would make them too dangerous to use as a potential therapy in humans because of the risk of cancer.

However, other recent findings show that excessively long telomeres can dramatically predispose people to cancer [4],[5]; more research is still needed to assess the cancer risks associated with telomerase gene therapy.

In 2019, Libella Gene Therapeutics, a Kansas-based company, launched clinical trials in Columbia for its telomeres lengthening therapy, based on delivering the TERT gene to cells, that contains instructions to build the telomere-rebuilding enzyme called telomerase. The move was criticized for evading U.S. federal law and for imposing a hefty entry fee into the trials of $1 million [6]. In 2020, Telocyte announced that, pending investment, it is ready to pull the trigger on Phase 1 FDA human trials of its Alzheimer's therapy, which involves a single injection of the telomerase gene that then re-lengthens telomeres within glia and neurons and resets gene expression [7].

Implications for R&I

- Effects of increased longevity on individuals: e.g. changing attitude towards life cycles, rites of passage, sense of urgency for and commitment to life's callings, appreciation of present moments, planning for the future; co-existing with other humans and with nature; search for the transcendent; attitude towards mortality, including potential pressures for euthanasia and assisted suicide.
- Understanding the impact of increased longevity on societies: e.g family structure and ties; inter-generational tensions related to e.g. access to housing, labor market, political power but also potential gains from the added experience and wisdom of older society members; impact on health care and social care.

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Let there be life

Main drivers: artificial reproductive technologies (among which IVG - In vitro gametogenesis)

By 2040, the use of in vitro gametes will allow people to be fertile until old age, it will help cancer patients have their own biologically related offspring; it will even make it possible for same sex couples to have their own children.

The bigger picture

In vitro gametogenesis (IVG) is a technique that allows reprogramming patients' skin or other somatic cells into stem cells, and then into egg and sperm cells. By 2040, IVG will change the landscape of romantic relationships and parenthood, unraveling new social norms: IVG will cancel the age limits on female fertility, allowing women to have related babies at much older age, beyond menopause. Women without ovaries - for example, because of cancer or surgery - might also be able to have biologically related children. Moreover, the technique could also allow same-sex couples to have genetically related offspring.

Family life, school life, work like, and more generally social life may have to adjust to many more old and same-sex parents. Such societal changes might deepen some tensions and frictions, especially in contexts where ageism and homophobia are already palpable. It's worth noting that resistance/repugnance towards earlier medical innovations related to reproduction, e.g. in vitro fertilization (IVF), was common when they first became available, but then public opinion progressively changed. Almost four decades of IVF practice proved that reproductive clinical and science communities handled ethically controversial issues with responsibility and dignity. Once ethical debates settle, it is possible that changing the landscape of parenthood through IVG will challenge societies to rethink, again and again, what a family and parental love really are, and how little they have to do with people's biological capacities.

Current signals pointing to this scenario

Older women represent the most rapidly growing age group having children, calling for major medical and societal adjustments [1]. Moreover, an estimated 15% of couples worldwide are unable to conceive a child naturally, causing feelings of sorrow, loss and a profound sense of inadequacy for many [2].

Some 9 million babies were born worldwide using existing versions of ART. Historically, ART techniques have been most popular in Europe, with over 900000 procedures performed in 2016 (ibid.) However, as improving IVF outcomes allow younger women relatively quick conceptions, older patients often linger on in the system [3]. This context will further extend the premises for research and maturation of various artificial reproductive technologies (ART).

Groundbreaking advances[1] are opening new, radical possibilities: One of them is in vitro gametogenesis, a technique through which sperm and eggs are created from patients'

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[1] There are other radical avenues, such as egg-producing artificial ovaries, artificial/exogenic wombs, reproductive cloning; some of them decades away in terms of feasibility; for brevity reasons, this scenario discusses IVG in particular, with the aim of exploring, more broadly, implications of extended fertility.

skin or other somatic (nonreproductive) cells, by reprogramming them into stem cells and then into egg and sperm cells.

Previously, human pluripotent stem cells (hPSCs) have been induced into human primordial germ cell–like cells (hPGCLCs) in vitro. In 2018, a group at Kyoto University in Japan reported a big step forward: they have cajoled human PGCs on to the next stage of development, called oogonia cells. It now remains to advance these further to the form called oocytes, which are ready to begin meiosis and become genuine egg cells [4],[5]. To this end, these cells require a somatic environment to develop fully as reproductive cells. In 2021, a team from Kyushu University managed to create the egg-supporting ovarian tissue from mouse stem cells. The team is now trying to repeat the construction of mini-ovaries with human stem cells, with the goal of using them to grow an egg [6].

Implications for R&I

- Creation of ovarian follicles containing oocytes equivalent to those found in the adult human ovary.
- IVG research to advance understanding of the cellular and molecular aberrations responsible for DNA defects that cause a range of inherited diseases; the use of gametes to study disease and development at the molecular and cellular level.
- Ethical consideration of IVG should guide ongoing and future research. There are currently a number of ethical concerns: Research may require the generation and destruction of numerous embryos; another fear is that this might lead to embryo farming. Moreover, if eggs become a manufactured resource, it could lead to wide-scale genomic selection and editing in embryos (currently there seems to be an understanding among researchers and regulators globally that gene editing should only be applied to somatic cells, not germ cells).

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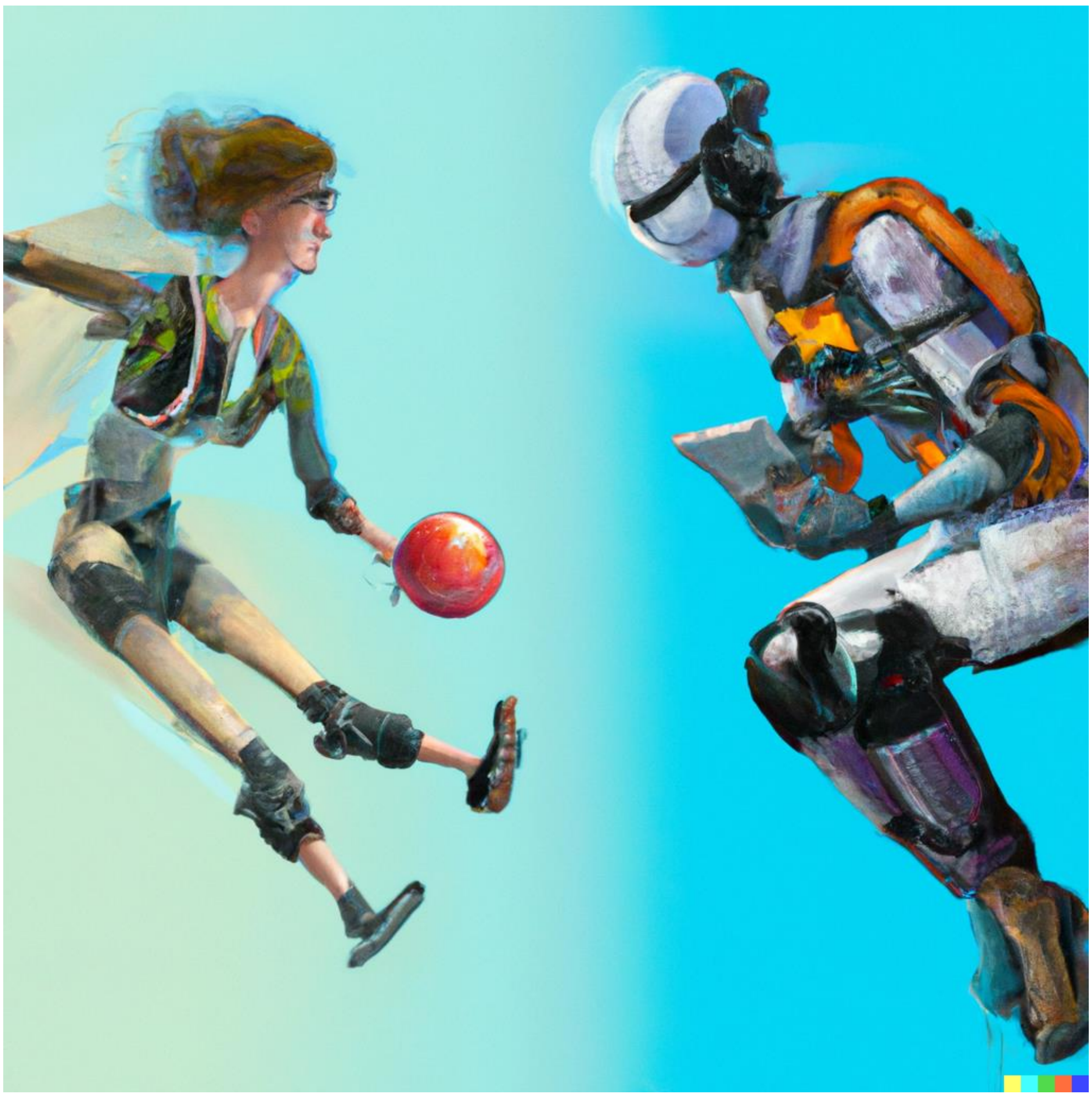
Extending human capabilities by embodying non-biological means

Second skin

Main drivers: Exoskeletons, Brain-to-machine interfaces

In 2040, a significant share of elderly people will be using exoskeletons for prolonging active life, for maintaining their mobility or as a form of assisted living. The premium versions will look like fitted suits that render the body motions perfectly natural, as they will be in sync with the brain and nerve activity and will use shape shifting materials to support movement.



Into this world

Ramona started using an active back support when she was 63, as a way of dealing with pain. Initially it was rather uncomfortable but after two weeks, the system, capturing nerve signals, became very well calibrated. She was wearing it most of the time and it felt like her own body. She was used to periodically changing the biocompatible layers. Every two years after, a new generation became available, boasting thinner material and better performance in recharging from the body motion. Some people upgraded like they did with smartphones in the 2020s, but Ramona was more conservative. She only switched to a version which included a complex of sensors monitoring her heart and lungs. As the information was available in real time for the doctors, she paid them less visits.

When she was 71, doctors recommended additional support for her knees and shoulders. Given the complex movement, the head band for sensing brain signals became part of the system. Initially she wore it only for the long morning walks, when visiting her son and the fresh market. Putting it on and waiting for the calibration took her about 20 minutes. Now, at 77 she is also wearing it in the house while cooking.

Most of her friends from the previous job opted for full body suits, the thin ones, not fully covered by the medical health insurance. “With the colored headband, and streaky outfit, you look like the gym fanatics from the 80s”, Ramona likes to joke.

The bigger picture

In 2040, exoskeletons will be a game changer for the labor market, allowing on average a 10 years prolongation of active life in numerous industries and services. Exoskeletons will be the gadgets of the 2040s, incorporating all the wearables, robotics and brain-machine interfaces. But, of course, the device will only be the entry point for a plethora of services, from medical advice to complex assisted living.

However, their use will not only address aging, but will increasingly enhance the work capabilities of people in their prime years. Some voices will ask for regulation of *bio-abuse*, defined as exoskeletons which are actually designed to mobilize the body, not just amplify the initiated movements. Things will be more complicated, as studies of body-exoskeleton interplay have not agreed on the level and dynamics of the dependency.

Given their socio-economic impact and the importance of their production industry, states will support their adoption, ensuring standard versions will be quite affordable. However, the technological race will be intense, and the premium models may reach exorbitant prices. Not rarely, old people, especially the ones without children, will invest a considerable amount in the exo-suits and the associated services, which they’ll perceive as their old age insurance.

Current signals pointing to this scenario

A plethora of passive exoskeletons have already been used in the automotive industry for years [1] and, more recently, powered exoskeletons are being explored by various automakers. “The technology, initially developed to aid people who lost the ability to walk or stand on their own, eases fatigue and helps prevent injury. It’s particularly useful for repetitive processes that can’t be automated” [2].

Exoskeletons are also used by elderly people in countries like Japan for prolonging work life [3]. The global production market for exoskeletons is expanding [4].

However, current versions are quite bulky and their activation is predominantly mechanical - based on muscular movement. Future generations may emerge from the continuous progress in the field of interfaces with the peripheral nervous system for the control of neuro-prosthetic limbs [5], and/or the brain-controlled exoskeletons for paralized people [6]. The use of new materials (e.g. liquid metal [7], shape shifting textiles [8]) may bring exoskeletons closer in appearance to a suit.

Implications for R&I

- The development of exoskeletons will most likely follow the pattern of a short cycle technology, with recurrent improvements on multiple fronts (from materials to soft electronics and brain-machine interface etc.). As an integrative technology, one in loop with human beings and potentially with collaborative robots, the development of exoskeletons will require advancements in the understanding of hybrid systems.
- Following the experience of smartphones, market domination by few global producers is a likely scenario, a fact that raises concerns about the transparency and credibility of the socio-psychological impact studies. A push for independent, open science studies is a must.

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Hyperconnected

Main drivers: brain-machine interfaces, extended reality technologies, machine learning algorithms, neuroscience

By 2040, brain-computer interfaces (BCI) will go beyond medical and military applications. Commercial application of BCIs will be mainstream in the gaming and entertainment field (e.g. neuro-gaming, immersive environments). Moreover, a growing number of people will leverage BCI tools to improve their performance at work, their learning outcomes, to control smart devices in routine tasks.

The bigger picture

People will enjoy BCI-based internet-browser applications, applications for relaxation, for learning or for enhancing artistic expression. BCIs will vastly enhance the experience in immersive virtual worlds, making it all feel more ‘real’, faster and intuitive.

BCIs will also be exploited in smart environments (e.g. smart houses, smart cars). For example, it will allow real-time device control or a BCI connected to a digital assistant will allow monitoring users’ mental state and adapting the surrounding components/ambient accordingly.

Multiple work environments will rely on BCI to improve efficiency, reduce cost and maximize operational performance. A relevant example is the exploitation of BCIs in human-robot collaborative settings (a warehouse, a factory, or any setting where semi-automated activities are carried): human operators will use BCIs to supply commands to the co-bot, or to switch between the independent and the cooperative modality of assistance. Moreover, BCIs combined with machine learning algorithms will provide insights into the engagement levels of workers, tracking whether they are focused or distracted. Running performance reviews based on analyzing and comparing attention levels will be a disputed practice.

Tensions will concern especially security and privacy issues. BCIs could be vulnerable to cyberattacks that expose brain data or interfere with a device’s function. Potential solutions for these issues could be as complicated as maintaining firmware updates to ensure the device has the necessary security updates to simply having a shutdown switch for the BCI device, should it be compromised.

Privacy issues will regard the complex spectrum of sensitive information generated by the monitoring of attention (e.g. that can be employed in work or education settings) or decision patterns (e.g. exploitable by retail companies), emotion recognition (e.g. exploitable in politics and in the entertainment industry). A continuous debate on privacy standards is the likely scenario.

BCI will probably create some competitive advantage, but not always for the benefit of the wearer. While some middle and top managers will use BCI for faster, better decision making, in the case of, for example, factory workers wired daily to better collaborate with semi-automated machines, the gain in productivity will not necessarily be reflected in higher wages. In any scenario, the issue of fairness regarding the use of BCI will be less about the price of the device, which will have been reduced drastically, but rather about who reaps the benefits of usage.

Countries with stronger inclination towards supervision and less preoccupation with the protection of users are likely to be test-beds for social experiments/engineering, providing the permissive environment for companies to advance such technologies. The tech winners could be those leading the market in one or more fields such as entertainment, platform services and production of semi-automated systems, which combine automated machinery with human labor.

Current signals pointing to this scenario

There have been major advances in mind controlled robotic devices using brain implants; some require invasive surgery while others don't (e.g. Neuralink, Blackrock, Synchron) [1]. As implantable BCIs will become ever smaller and less invasive to implant, more users will adopt them, including for non-medical purposes.

Non-invasive BCIs are less accurate, but the ease of use makes them appealing in multiple settings. In 2021, the Food and Drug Administration authorized the first wearable BCI for rehabilitation - a device that uses a wireless EEG headset to help stroke patients regain arm and hand control [2]. Outside the clinical space, some companies are developing BCIs that can be worn like a hat. NextMind's wearable lets users move objects on a screen, and Muse provides auditory feedback to help users meditate, but also to "help employees lower stress, increase resilience, and improve their engagement". Other headbands on the market also provide insights into the engagement levels of users/workers [3]. Moreover, new technological pathways are emerging: for example, Kernel Flow is a wearable headset that measures brain activity by recording local changes in blood oxygenation. Recently, Kernel Flow neuroimaging technology predicted which game players were high or low performers [4].

Developing BCIs depends on the availability of sufficient, reliable data, such as EEG (electroencephalography) data. BCI-related datasets from research labs are becoming increasingly available [5]. Moreover, open-source projects such as OpenBCI [6] are making affordable hardware available to new potential market players. Data from real-life environments will become increasingly accessible once more commercial BCI enter the market.

As BCIs might be the next frontier of human computer interaction, more companies are interested in investing. Funding in BCI funding in 2021 was approx. $300 million globally - three times more than in 2019 [7].

Implications for R&I:

- Maturing key components of the BCI technology for increased usability: e.g. improving neural sensing technology, including sensors and AI; more precise and less invasive brain stimulation; more generalized BCI models with little or no calibration requirement.

- Health/safety impacts and neuroethics of BCIs, including addiction risks and BCIs' potential to affect people's agency, autonomy and free will.
- Security threats for BCIs, brain data protection (neural security) and data governance.
- Socio-economic impact and risks: Equitable access to BCIs as enhancements for working and learning; possible exploitation of vulnerable groups using BCIs for increased productivity in work settings.

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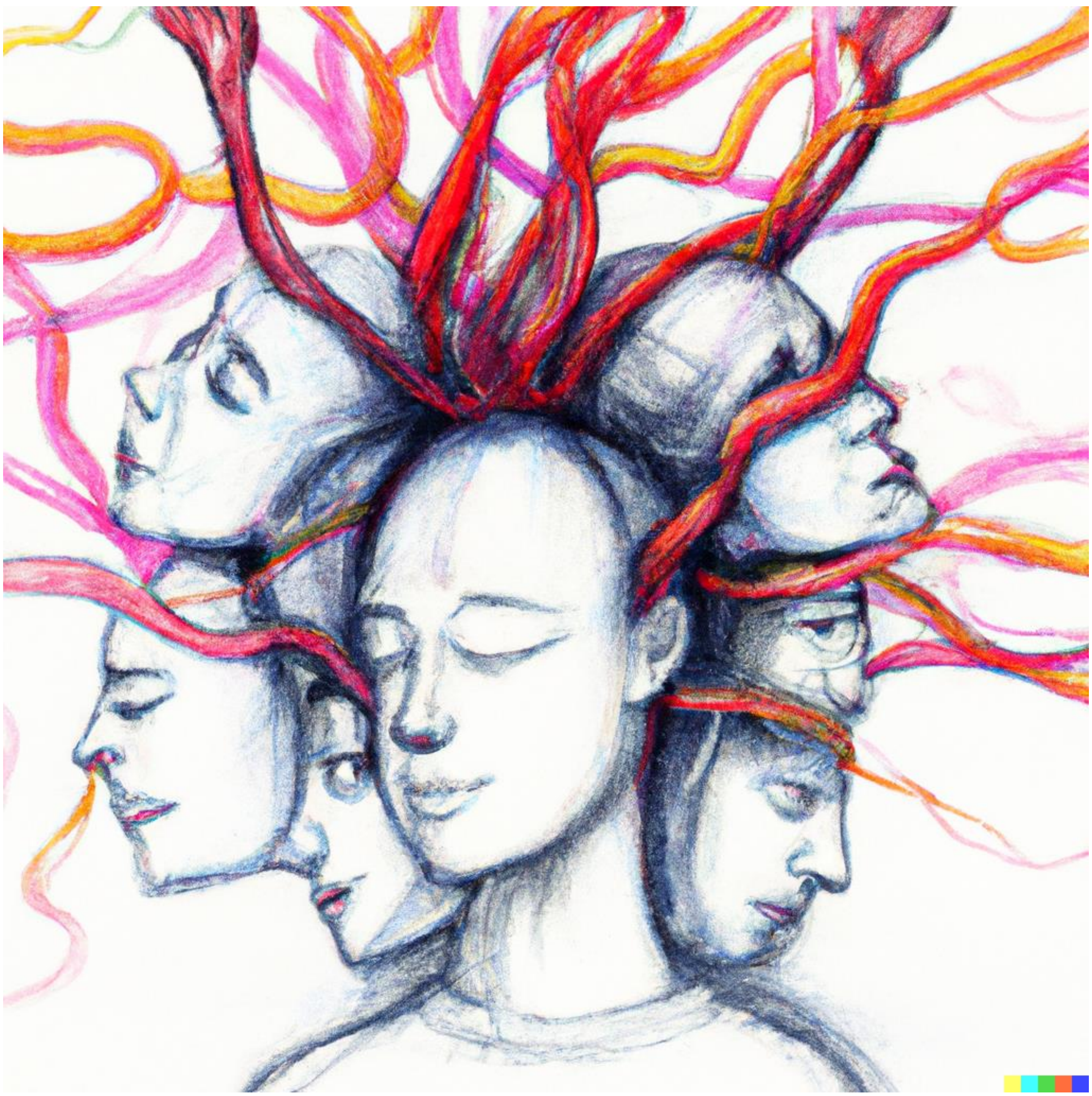
Hive minds

Main drivers: Brain-to-brain interfaces, Emotion recognition technology

By 2040, numerous people will be part of brain hives. Real time sharing of emotions will play a key role in creating communities of trust, diverse in their focus and culture. Brain-to-brain interfaces will accelerate and diversify intra-community sharing, creating strong collective neurofeedback loops, gradually conducing to convergent behaviors and co-dependence. Some prominent hives in particular and the culture of sharing in general will be challenging the fabric of society, from the structure of companies, to life-work separation or the definition of family.



Into this world

In 2030, Maria was among the pioneers in providing ‘credible reviews’ for electronics, i.e. unboxing while sharing her emotions as they were monitored in real time by a complex of wearables. People soon became very interested in this kind of sincerity, so she created a community of trust, with people discussing various topics while sharing their emotions. By 2040, she sees her community continuously expanding, organizing more and more face-to-face events. Several times they find themselves on the brink of splitting into multiple, more specific cultures of trust.

Mark is part of a collective brain for a multinational company. Almost all the important decisions in the organization are made by this group of 101 people, carefully chosen and able to collaborate at an unprecedented level in the MediumX, an environment supported by brain-to-brain (B2B) technology. It took him three years to integrate. For him, it was a crucial journey, knowing that he might not want to invest that time again, nor go through the emotional turmoil of joining another hive.

Anton’s hive is a group of geeks wired through brain-to-brain technology; they are getting rich by speculating at the stock exchange. He is not into money, but he is very enthusiastic about his peers - they hang out a lot. The group is his world and he started having limited interactions outside the hive.

Maya is not part of a community, but she and her boyfriend started using B2B tech as a means of effectively sharing their emotional status and an ever-evolving set of dispositions, to which they gave specific names. She feels they have developed a new, rich language, one in which they can express more genuinely. They are half joking about introducing their dog into their small hive, as its emotions are paramount in the unfolding of the day.

The bigger picture

The youth of 2040, avid B2B users, will complement oral and written communication with instant sharing of emotions and feedback ‘primitives’, automatically read from the brain, just as the youth of 2020 communicated extensively via memes and emoticons. The instant, less filtered interactions will blur not only private and work environments, but also the boundaries of socially accepted expression. The new levels of expression and sometimes mutual trust will serve as premises for a tumultuous cultural revolution.

Automated emotion sharing and mediated collaboration will coagulate very diverse communities, where people are more or less brain-wired in groups for all or most of their time. Given the life encompassing associations, most communities will tend to cover not only one, but most aspects of life, thus becoming real communes, often diverging from the mainstream social construction of reality.

Such collectives will be like living entities, some with incredible success and fulfilling lifestyles, and others facing structural challenges, collective health problems, similar to bee hives, and potentially ending in collapse. It will be generally accepted that people adhering to a hive may have huge exit costs.

As history shows, some communes will become very strong, some will fade, while mergers and splits will also be frequent. Society will be repeating its inner struggles, this time on two layers: the clash of networks and the exploration of deep human collaboration.

Current signals pointing to this scenario

“The interest in emotion recognition and practical implementation of this technique is steadily increasing and finds more areas of application”. Current methods use sensors (e.g. for Electroencephalography, Electrocardiography, Heart Rate Variability, Electromyogram, Electrooculography, Galvanic Skin Response, Respiration Rate Analysis, Skin Temperature Measurements) or visual analysis (Facial Expressions, Body Posture, and Gesture Analysis) and Voice analysis. The best models use a combination of those inputs and machine learning for data analysis [1].

In 2022, Microsoft announced it will remove several features from its facial recognition technology that deal with emotion. The reasons provided refer to the immaturity of understanding/differentiating emotions and the social acceptability of sharing them [2]. Other solutions are still available on the market, promising monitoring in real time, but in an impersonal way, the emotions of participants in teleconferences [3].

A growing interest is manifested in the science of collective intelligence. For instance, "The MIT Center for Collective Intelligence explores how people and computers can be connected so that —collectively—they act more intelligently than any person, group, or computer has ever done before" [4].

Particularly interesting is the progress in cooperative problem solving by humans using a “social network” of connected brains, piloted in a Tetris-like game [5].

A promising frontier of research is that of defining life ensembles (from cell to organs, organisms, colonies) in terms of information theory [6].

Implications for R&I

- Additional research is needed to improve brain-to-machine and brain-to-brain technologies, to guarantee the credibility of results, to reduce invasiveness and to achieve miniaturization.
- A great challenge lies in better understanding the impact of these technologies on individuals, the physical and mental health implications and the socio-psychological costs of leaving/changing hives.

- Better understanding will be required regarding the dynamics of the human hives, covering topics like co-dependence, behavioral convergence, collective health and structural challenges of the hives. Also, research will be called to explore the broader social implications of the hives, tackling problems like collective identities, hive-society interaction, hive-hive dynamics or fringe hives.

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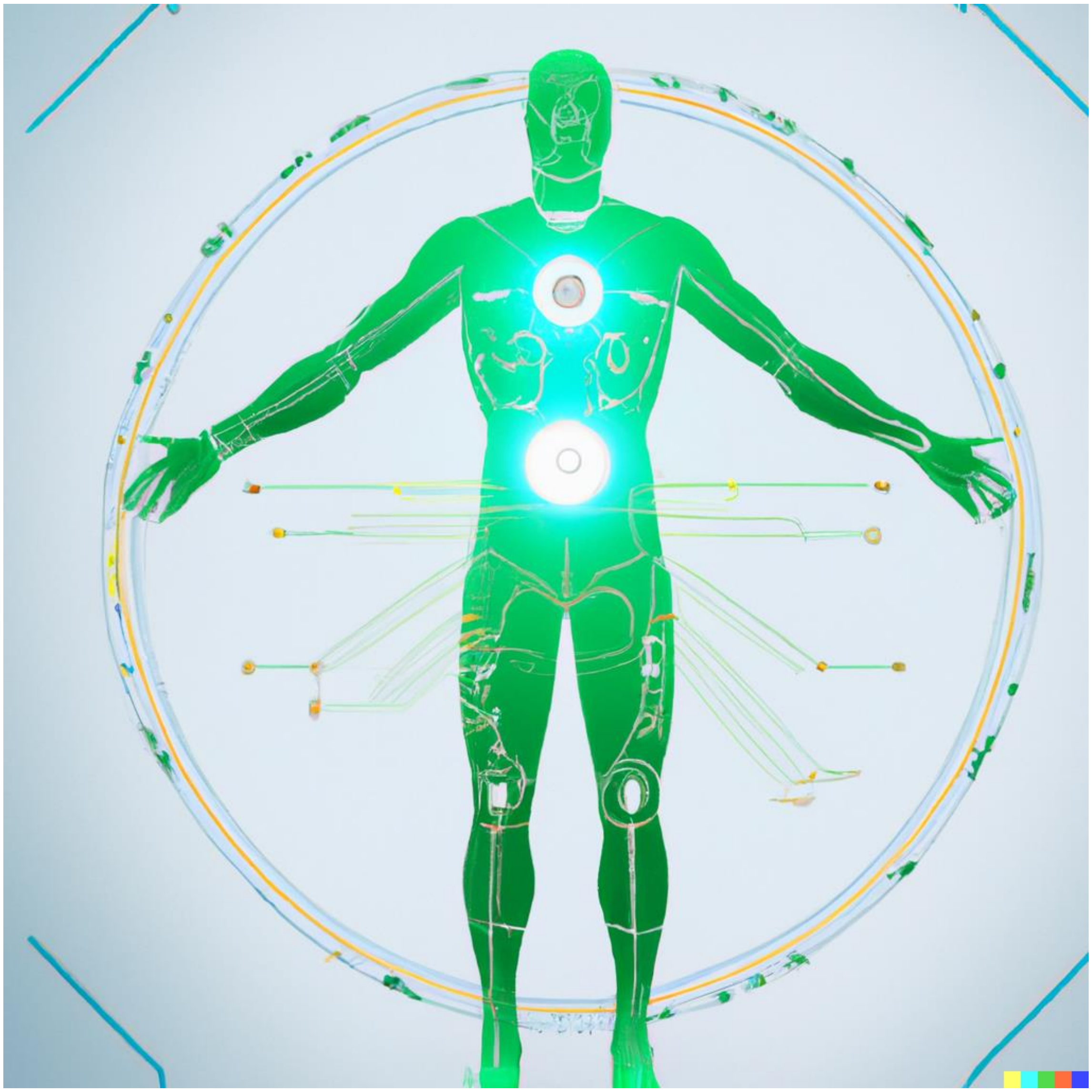
Simulation and replication of the human body and mind

Digital body twin

Main drivers: computational modeling, sensors, predictive artificial intelligence

By 2040, many people will be riddled with technological sensors, both wearables and implants, permanently monitoring their health and body functions. The interconnection of these sensors and the additional use of genetics and environmental data will enable the creation of a digital body twin [1], allowing alert signals for disease prevention and the simulation of the short- and long-term effects of any behavior on one's health, body and life expectancy.



Into this world

Mike learns from his digital body twin that he should not start a job as a bus driver because this would entail important risks for his health and life expectancy. Laura, in contrast, learns that there is nothing to fear if she goes on a six-month trip through South America, including malaria areas. After a stressful time at work and at home, Chris increasingly receives health alerts and decides to get a check-up at his doctor. Cathy decides not to consume nuts because this might result in a proper food intolerance.

The bigger picture

In 2040, digital body twins will be at the forefront of personalized medicine. Digital twin models will be continuously fed with various types of information during the lifetime of an individual. This will allow to determine what the statistically normal patterns are for that person for a manifold of parameters (e.g. molecular, phenotypic etc.).

They digital body twins will likely be provided as a service, and generically will include renting and integration of data collection sensors (mostly body related, but also environmental ones), feeds from additional sources (e.g. names of medicines ingested, or tags of life events that are estimated to have produced shocks), the body simulation and the feedback system (i.e. prediction, alert and advice for the person and/or integrated into the workflow of professional doctors).

Such services will probably be supplied by tech giants, who will be in a race for continuously improving their prediction (simulation) power, not only by updating their sensors and modeling technologies, but also by learning from massive datasets. Also, these platforms will become key players in the process of drug discovery and testing. These combined interests will keep the costs of non-premium versions relatively low.

EU regulations will guarantee the access of citizens to their historical body data, but their reuse by other service providers will remain limited, as the calibrated models will not be part of the data repositories.

Energy consumption of these digital twin platforms will be high, as savings brought forth by new, more economical technical solutions will be surpassed by the costs incurred by increased accuracy.

New tensions in this world concern aspects such as: Do people have the strength to ignore the feedback from digital body twins? They might reveal terrible or even life-threatening effects of a certain behavior which may, however, be unavoidable for the individual. Will people then become very anxious about what might happen in the future? Will people be able to make autonomous decisions under the influence of algorithms claiming to deliver the optimal, data-based actions? In addition, the collected behavioral data (e.g. location and level of activity, sleeping and nutrition patterns) could potentially be used for other purposes, such as controlling the adherence to health recommendations by insurance companies, or using the data as a predictor for criminal behavior. The digital twin may even be hacked and manipulated. Finally, other issues concern societal values like justice or sustainability: Digital twinning may create sharp divides in access to truly personalized health care. What will qualify as therapy or as enhancement? Could other functions, such as providing feedback on the individual environmental footprint, be integrated into the digital body system, contributing to the twin transition?

Current signals pointing to this scenario

Technologies that could contribute to the digital body twin are already in use, including heart-rate monitors, wearables, sleep pattern apps, and portable diagnostics devices. There are ongoing and fast improvements in sensor technologies, including approaches such as vocal biomarkers [2], tattoo-based sensors [3], insideables [4], nanorobots [5].

Interdisciplinary organizations such as DigiTwins [6], or the Swedish Digital Twin Consortium [7] have emerged to drive the application of digital twins in personalized medicine. Companies are also investing in research in digital twins in healthcare, for example Philips [8] or Siemens [9] or start-ups like Twin Health with its Whole Body Digital Twin [10].

Implications for R&I

- Improving digital twins of the body through, for example, greater availability of biological, clinical, behavioral and environmental data; energy efficient simulation models and technologies.
- Digital twins' impact on a person's identity and on the societal perception about that person; the potential of making differences between people sharply defined and transparent to lead to segmentation and discrimination.
- Moral and ethical inquiry needed as a result of conceptual changes in distinguishing between disease, asymptomatic illness and health and, consequently, therapy, preventative care, and enhancement, in light of patterns found in the high-resolution data of individual patients, but also informed by normative interests and conventions.
- Governance structures that ensure transparency of digital twins' use, protection of data, fair distribution of the benefits derived from people's personal biological information

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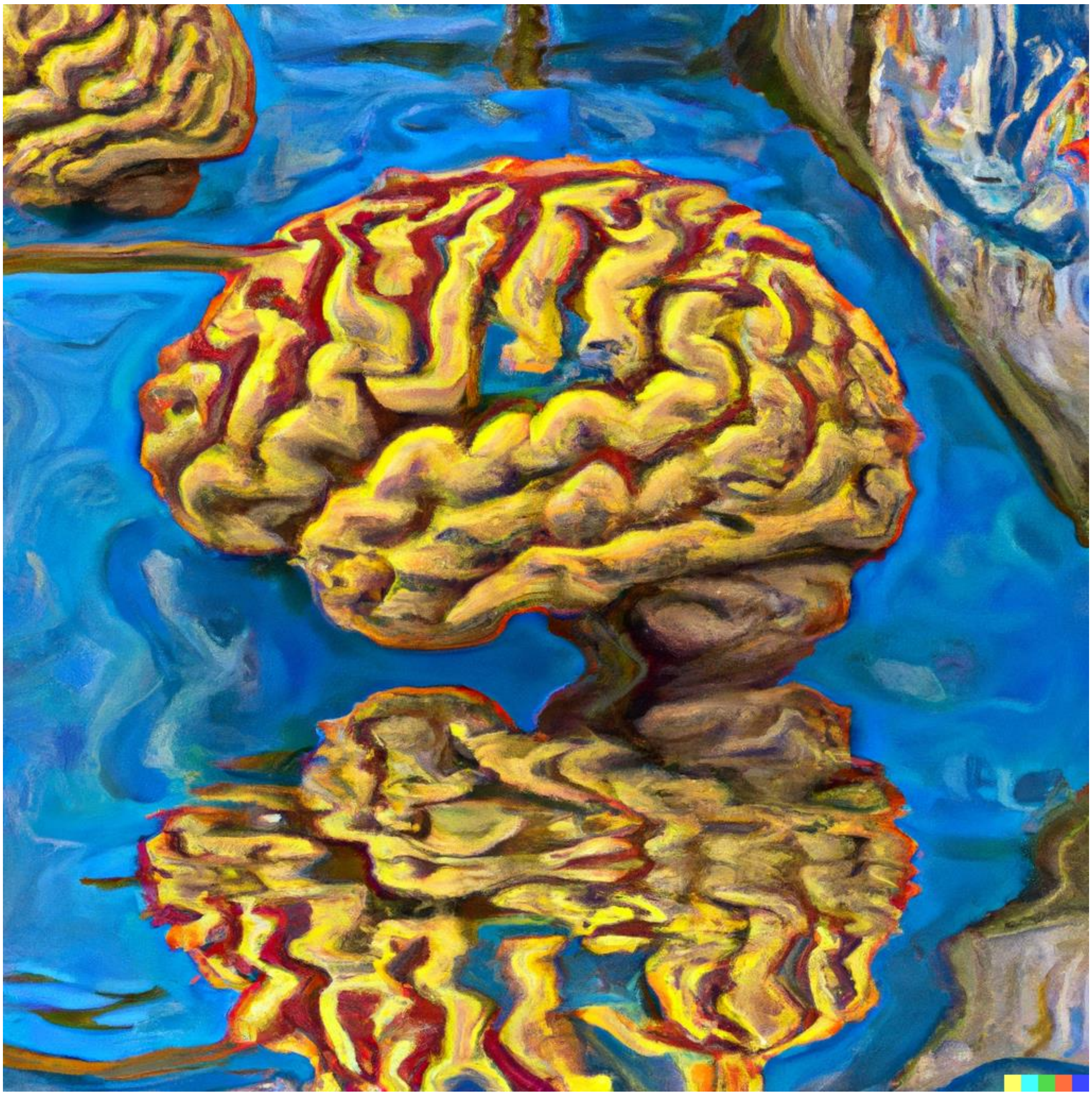
Brain in the mirror

Main drivers: digital twin of the brain/virtual brain

By 2040, it will be possible to accurately scan the physical structure and the dynamic function of the human brain and to transfer this brain *hyperscan* onto a computer in digital form. The computer would then run a simulation of the brain's processes, such that it would respond in essentially the same way as the original brain.



The bigger picture

The concept of “digital twin of the brain” or “virtual brain” refers to a computational model of structural or functional relationships in the brain, aimed at understanding the human brain in general, and at developing more personalized brain interventions in particular. Thus, a brain twin is not a digital replica of a whole real counterpart brain, neither of all processes within a real human brain.

Such brain models can attain different levels of (patient) specificity. Computationally defined architectures can become more ‘personalised’ when individual/subject-specific data are used as optimization constraints, where the degree of personalization is a compromise between, on one hand, anatomical and functional utility and, on the other, biological realism [1].

Digital twins of human brains will be used to test hypotheses in cognitive science, responses to different types of treatments, in mental health studies, in social psychology and neuroscience by also simulating the interaction among different models. This would enormously reduce the usage of animals in brain research, as many studies will be conducted in silico. Moreover, the brain twin will allow reducing risks and optimizing processes in drug development, as accurate simulations of brain response and iteration can be conducted. Going beyond, in a much further long term, such models may mimic cognitive tasks as well, which can be used by real brains to have their behavioral outcomes simulated.

Challenges are inherent when a simulation – a digital brain twin – is representing the actual brain of a person in contexts where medical decisions or otherwise are being made. The act of representation is in fact a special kind of interaction between the person and their brain twin, and it is of utmost importance whether the person has the power to decide the application in which their simulation is being used. This relation is further complicated by the fact that the digital twin is not just representing an actual person in certain contexts, but may also exercise power over a human’s life by being able to predict smaller or larger parts of a person’s future [2].

Another challenging aspect is whether the current data privacy regulations should be applied to digital twins or a new regulatory framework is needed. Tensions here arise also from the fact that digital twins in general span both physical and virtual worlds.

Moreover, it is possible that once a certain level of complexity is attained, the digital twin may be considered conscious/sentient. In this context, a debate may emerge as to whether studies shall be conducted under exactly the same ethical principles as with human beings.

Current signals pointing to this scenario

The field of brain modeling is improving at the confluence of more accurate brain sensing, statistical physics and high-performance computing. The Virtual Brain project is already offering simulations of the full brain [3]. Other projects, like Neurotwin [4], are focusing research on the usage of hybrid brain models for simulating brain health electrical stimulation treatments. These simulations can be improved through the application of High-Performance Computing as done in the Human Brain Project (HBP) and other international initiatives [5], which had precisely a high-resolution multi-level full brain model as their original aim. Indeed, HBP will become EBRAINS [6], a digital research infrastructure that will be made available to the research community for advancing brain research. Such advances in brain modeling technologies have opened the debate on the neuroethics of brain digital twins [7].

Behavior simulation resulting from brain simulations is difficult to achieve by 2040, but in the long run, because it includes solving several and fundamental unknowns in neuroscience. Complete full simulation might be substituted by a predictive AI system as already done in some cases [8].

Implications for R&I

- Confluence of massive sensing platforms, mathematical dynamic modeling and high-performance computing for simulations of real brains in real-world scenarios.
- Breakthroughs in high-resolution simulation techniques linking different system scales from the molecular through the network to the full Central Nervous System level.
- Ethical implications regarding the usage of organ digital twins in general, and of the brain in particular.
- Development of a regulatory framework for behavioral and clinical research with organ digital twins.

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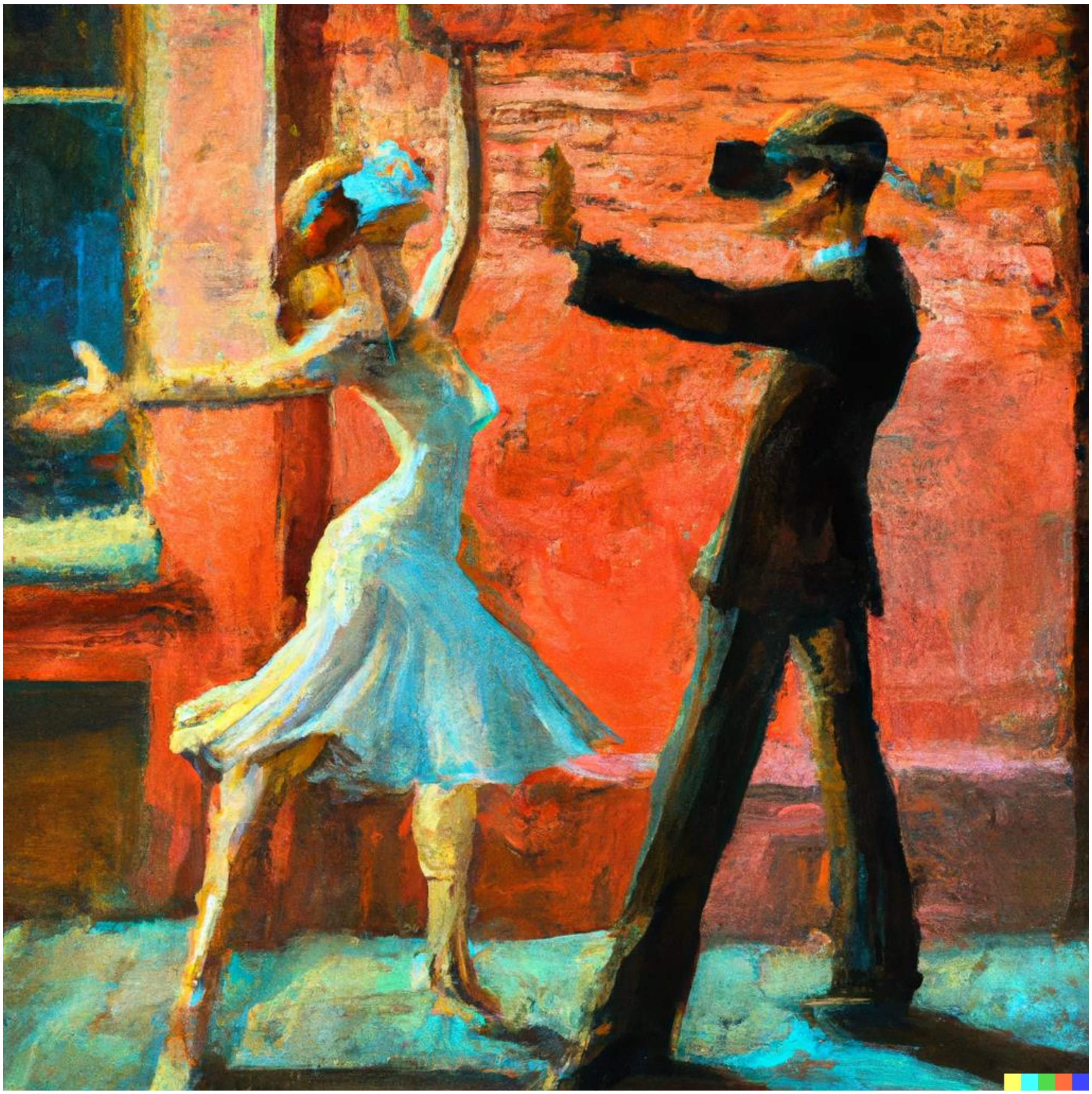
Double life

Main drivers: Virtual reality technologies, increased bandwidth and computing power

By 2040, digital immersive worlds will be part of daily life for hundreds of millions of people globally. Interactions will take place among humans and automated entities, in gaming or fantasy worlds and in 'mirror worlds' replicating real-life environments. Virtual worlds will open numerous opportunities for people to 'author' themselves quite intentionally and experimentally. Some users will see their avatar as more real, as in authentic, than their material, social selves.



The bigger picture

The physical world may become inhospitable for a large number of people. Whether it's because of waves of pandemic disease, the impacts of climate change, the deteriorated social fabric in large cities or elsewhere that causes crushing loneliness, some people will engage persistently in virtual worlds. Others will choose to join virtual realities to enrich/complement their physical lives. The scenario speaks of people who will choose to be almost constantly plugged into virtual worlds; the vast majority of people will join only for specific activities – work, learning, traveling to new, virtual spaces; diving in and out of virtual worlds will not significantly alter their actual lives.

Software, hardware, user interfaces and network capabilities will be more potent and sophisticated, and thus able to create a much more refined, immersive and better-functioning user experience (the aspect of zero latency still not guaranteed). For those living in 2040, the virtual world(s) will provide a wide range of increasingly immersive social encounters and intense experiences, through improved sensory stimuli via ubiquitous wearable devices, that include and go beyond visual (most likely through eyeglasses/contact lenses) and aural experiences.

Immersive online environments will be created and maintained by giant companies with impressive data centers. It's possible that there will be multiple competing virtual worlds, just as we currently have competing social media platforms. The features and attributes of a user might be platform specific - non-transferable between the various virtual environments. One provider might end up dominating the market and gaining monopoly control of the virtual world(s).

For some people virtual worlds will be an opportunity to free themselves from the limitations of the physical world. Being themselves will mean being their virtual self. People who feel disenfranchised or misunderstood in the 'real'/physical world might find new ways to communicate, connect and participate as fully as they desire in social interactions.

Fully-immersive digital spaces will probably create new divisions in society, for example between those whose many life experiences occur in virtual worlds and those - the majority, actually - who will remain anchored in the physical world.

Moreover, while for some, digital personas would allow for creative and genuine self-expression, for others they would contribute to psychological dissonance, toxic artificiality and deception, social and self-alienation. In some cases, the immersive mirror-worlds might have severe psychological impact causing, for example, multiple-self syndrome.

The sense of togetherness in a virtual community might also mean, in some cases, less burden on the physical world, in terms of, for example, environmental pollution and exploitation of nature. On the other hand, it's important to acknowledge that virtual immersive worlds require enormous computing scale and power; their energy demands will be massive.

The darkest forces of virtual worlds will be unavoidable. There will be increased opportunities for harassment, bullying and sexual exploitation, manipulation and misinformation that will deeply affect the lives of participants in the virtual worlds, with consequences spilling in the physical world. Immersive virtual worlds will be prolific spaces for government or corporate surveillance, and even within families

Current signals pointing to this scenario

Tech giants such as Amazon, Apple, Meta, Google, Microsoft, Roblox, Samsung are already deeply invested in the field of immersive virtual worlds [1] and will continue to be with the aim of building more immersive, comprehensive virtual experiences.

Young people, but not only, are already early adopters of immersive gaming environments, and they will be the ones likely to be among the initial inhabitants of other virtual worlds. Large communities aggregating around their passions show how niche phenomena can grow tremendously: for example, e-sports have evolved from underground culture to mainstream industry, some niches are seriously competing with physical sports in terms of revenue, or even surpassing them in terms of viewership [2].

Social VR is of particular interest, as people long for human interaction and connection. For example, in 2021 and 2020, the iconic desert festival Burning Man moved into the virtual world. In 2020, half a million people attended, a five-fold increase compared to the physical attendance in 2019 [3]. Sharing experiences as an avatar proved to be incredibly rewarding and enriching. Besides being an arena for entertainment, social VR's combination of anonymity and togetherness proves a safe space for people to engage with earnestness in processing deep pain and complicated emotions, sometimes forging friendships along the way. For example, EvolVR is a virtual spiritual community where sharing through an avatar liberates people to be honest and vulnerable about terminal diseases, the difficulties in their marriages, their parents and friends who'd passed, their childhood traumas [4].

Implications for R&I

- Long term impact of immersive technologies usage (e.g. brain wiring, dependency, social integration).
- Social dynamics in virtual environments and implications for physical life.
- Implications for planetary resources (e.g. energy).

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We'll meet again on the other side

Main drivers: Deep fake technology

By 2040, deceased people will exist in cyberspace: Virtual Deceased Persons (VDP) [1],[2] will be capable of interacting with the living ones using natural language and will have a realistic visual appearance. Their personalities, facial expressions and language will be similar to the traits of the deceased person.

A more radical scenario is where VDPs are granted decision-making power. This would also imply legal changes and would feed into the overall debate on the autonomy of AI (e.g. if a VDP makes a decision affecting others, who is responsible?). Also, as grief tech will get more sophisticated, VDPs might seem to living people to be sentient and have a consciousness. While most AI experts seem to think that sentience is not achievable, even at the time horizon of 2040, it may be possible to code a digital immortal that appears to do much of the things that define sentience.

The bigger picture

The new technology will change the way people grieve, creating a new culture, rituals and customs. Talking to a deceased parent, a partner or a friend, maintaining some of the intimate connection enabled by their voice and mannerisms, seeking comfort in difficult moments or opening up conversations that should have happened during their lifetime, allowing the deceased to be part of important life events like weddings or graduation ceremonies will definitely blur the boundaries between the living and the dead. For some, this connection will fade away once the pain of acute grief begins muting, whereas for others it will be more permanent, like a shadow accompanying them for many years. In some cases, the digital replicas of the deceased may pose mental health risks: acute grief could intersect with, or even cause, mental illness, especially if continuously being fueled and augmented by reminders of the person who’s passed away.

Grief tech will most likely have implications beyond the small circle of friends and family of a deceased person, opening new ways of managing their intellectual or spiritual legacies: for example, it will be employed in passing on corporate knowledge from employers who passed away. Furthermore, great thinkers - scientists, philosophers, religious figures, political leaders - will engage in discussions on various issues as VDPs, drawing in new audiences.

It is also important who initiates interaction with the VDP, is it the VDP itself approaching the living one? What to do with VDPs that nobody interacts with (virtual abandoned graves)? What would be the rules of interactions between VDPs and real people? In social media (if it still exists in 2040), will there be a warning differentiating between profiles of real people and VDPs?

Current signals pointing to this scenario

A startup Deep Nostalgia [3] offers animating old family photos to keep alive memories of deceased family members. Startup Eter9 [4] analyzes social feeds of people to carry on their activities post-mortem. HereAfter [5] and StoryFile [6] interviews subjects for hours while they are still alive, on topics ranging from childhood memories to first dates, and all sorts of life changing events. After they die, their life story is preserved through voice and even video replicas that engage with the ones who are grieving. You, Only Virtual [7] and a few other startups want to go beyond recounting memories, to capture the intimacy of a relationship between two people. Such services allow people to build a bot by uploading someone’s text messages, emails, and voice conversations, capturing massive amounts of data over months or even years. For example, programs such as Project December [8],[9] are 're-creating' dead loved ones using NLP (a piece of software known as GPT-3) which manages to write things that are poetic, witty, and emotionally appropriate.

Implications for R&I

- Psychological and social consequences of grief technology e.g. individual/collective perception of aliveness, evocation vs. authenticity, attitudes towards (im)mortality, cultural norms embedded in mourning and grief; socio-political understanding of death, post-mortem veneration, legacy of the dead.
- As grief tech will mature in the wider context of artificial/digital agents, R&I will be engaged in the improvement of interaction technologies; the legal status of avatars/virtual persons (be them deceased or not); along with educational efforts to expand digital literacy - skills to identify VDPS and, more generally, virtual personas/deep fake creations.

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The impression of being alive

Main drivers: sophisticated machines that perform as if sentient/conscious

By 2040, almost all daily life operations will imply interacting with an artificial agent. At that point, many people will either live under the impression that their interaction is with an actual human or they will prefer to engage with them 'as if' they were real people or non-human sentient beings. Users may often experience the feeling that some of these systems have developed consciousness, a sensation evoked by the level of complexity of the underlying computational procedures (e.g. self-reflection, global on-demand availability of information, development of value system, affective computing) and the sophistication of the interface (including e.g. natural language communication, android robotics, multi-modal interaction).

The bigger picture

Artificial entities – in the form of software agents or embodied as robots – will perform sophisticated imitations of not only human intelligence, but also of self-awareness and sentient behavior that will be nearly impossible to distinguish from the actions of an actual conscious being. People will increasingly seek companionship with artificial assistants, confide in simulated therapists, learn from virtual teachers, change habits as instructed by robotic wellness coaches, flirt with chat-bots posing as charming potential partners on online dating sites, develop close bonds akin to friendship with robotic companions, pets or co-workers, rely on the tireless and calm efficiency of robot orderlies in care-homes. Engaging with seemingly conscious, and even seemingly sentient artificial agents will expand and challenge our understanding of empathy, care, attachment based on nurturance, responsibility, deception (whether benevolent or not).

Some voices argue that robot companions may win people's hearts with their pleasant imitation of human company, without the inevitable frictions and irritations that come with real, imperfect, moody people. Many may come to prefer their companionship, whether as therapists, friends, sexual partners, or caregivers [1]. There is no doubt that artificial agents will become better at sustaining the illusion of them knowing us intimately and caring about us deeply. But important questions remain open: what kind of humans will we become, what value will we ascribe to the reciprocal pleasure in relating with other people, how will we perpetuate a shared humanity?

While a plethora of artificial entities will be primed to be beneficial to people, it's inevitable that seemingly sentient artificial agents will also be created with the purpose of influencing human beings to behave in a way that will benefit the company that produced them. Artificial beings may be trained to exhibit emotions, positive or negative, in order to, for example, encourage people to purchase certain products/services, or support a certain public figure, or to allow the robots access to private conversations.

Current signals pointing to this scenario

An estimated 10-15 percent of users on the influential social media platform Twitter are bots. [2] AI technology is writing articles and books that read the same (occasionally even better) as a human writing them [3]. Programs such as Project December are 're-creating' dead loved ones using NLP (a piece of software known as GPT-3) which writes things that are poetic, witty, and emotionally soothing. Vtubers, computer generated celebrities who are fully autonomous, draw in numerous, emotionally engaged fans who are trying to ease their loneliness, or are earning for romance, fantasizing about idols of all sorts [4]. Companion robots are becoming more apt in simulating/displaying emotions, with some models integrating emotional cues in their facial expression or body language [5]. Simulated therapists such as Cogniant and Woebot are currently helping people navigate their emotions, with several such products adopting cognitive behavioural therapy (CBT) procedures. Some studies indicate that therapy with an artificial entity is both cost- and psychologically effective—and well liked.

Recently, the LaMDA Google system has sparked a debate on its sentience capability. Although the discussion has ended up with a general opinion among experts that the LaMDA system is not actually sentient because of merely reproducing dialogue excerpts taken from sources of text available on the internet, the controversy and its global impact show the potential of the topic to raise a social discussion reaching non-expert communities. The debate might be seen as a modern proof of AI-based machines passing the Turing test [6]. At the core of the debate we can find the definition of consciousness. Recent works in several research domains, e.g. psychology [7], computational biology [8], propose consciousness to be as an emergent property of a system with a sufficient level of complexity. In a similar research arm, the confluence of neuroscience and complex systems research has been developing for some years [9] and may generate a new theoretical framework of consciousness [10]. The topic may benefit from current developments in computing paradigms like neuromorphic [11] or quantum computing [12], which present computational properties very different from current sequential machines. Indeed, existing theories of consciousness like the Global Neuronal Workspace (GNW) already claim the 'possibility that consciousness arises from specific computations' [13].

The aforementioned debate is one on the ultimate understanding of human nature and therefore may spark different, even contradictory reactions in research communities. As an example, we find a recently published proposal for a twenty-year long veto on machine consciousness research [14], which claims the possibility of artificial consciousness provoking artificial suffering. On the other hand, the impossibility of artificial consciousness is at the core of different theoretical developments. Searle's Chinese room thought experiment [15] has been interpreted as leading to the conclusion that computer programs can't develop neither intelligence, i.e. 'real understanding', nor consciousness [16]. The Chinese room thought experiment was proposed in 1980, and therefore it seems high time to address the fundamental limitation it imposes on AI through new research paradigms. Furthermore, the Information Integration Theory of consciousness tends to claim the impossibility of feedforward sequential systems to show consciousness [17]. However, this claim seems to oversee recent developments in computing paradigms as the ones mentioned in the former paragraph.

Implications for R&I

- Social and psychological implications of human relationships with seemingly conscious/sentient machines.
- New computational paradigms leading to artificial consciousness and efficient tests to prove it.

- Development of a multidisciplinary research domain on human and artificial consciousness, suffering and sentience.
- Unified theories of consciousness.

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