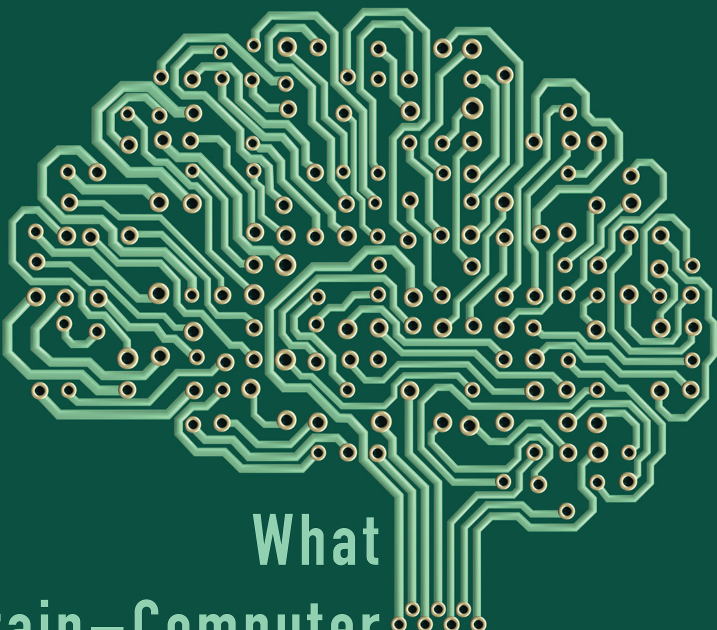
CYBORG MIND



What Brain–Computer and Mind–Cyberspace Interfaces Mean for Cyberneuroethics

EDITED BY

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INTRODUCTION

The seventeenth-century French architect, physician, anatomist and inventor Claude Perrault (1613–1688) is best known for designing the front of the Louvre Museum in Paris. But he left another legacy. Eleven years after his death, a small book was published entitled *Recueil de plusieurs machines, de nouvelle invention* (*Collected Notes of a Number of Machines, of New Invention*). The book contained a description for creating an advanced form of abacus, an ingenious calculating machine. This piece of equipment would, Perrault believed, be of great use to a 'computer' – a physical person who performs mathematical computations. In coining the term 'computer', therefore, he had in mind a physical person rather than an object.

But history has a curious way of reassigning the use of language. For Perrault, the person was still the principal calculator, while his machine was a tool to help the user perform calculations. Though he believed the machine would have its uses, the person was clearly more capable.

Time, however, has moved on! A half-decent office computer now performs more than a billion calculations every second, selecting data from many billions of items stored locally on computer disks or chips. As a result, for some kinds of tasks, the machine can outstrip its master. No longer is it appropriate to think of the physical person as the computer; instead, the term is more appropriately assigned to the machine. Moreover, until now, the two have been discrete entities. On the desk sits a machine – an object. At the desk sits a person – an agent.

However, the boundary is again beginning to change and become less distinct. With direct interfaces slowly being developed between the human brain and computers, a partial return of the term 'computer' to the human person may, at present, be seen as a plausible prospect.

Given this, what possible ethical and anthropological dilemmas and challenges would exist for such a machine-person? What would it then mean to be human? Many studies have examined the brain and nervous systems, which are often characterised by the prefix 'neuro'. Many others have considered computers as well as the information and network technologies characterised by the prefix 'cyber', and many more have discussed ethics. However, this introductory work is the first to draw on all three together in order to address the ethical and anthropological questions, challenges and implications that have arisen with respect to the new neuronal interface systems in both medical and nonmedical contexts. These describe devices that enable an interface between any neuronal network (including the brain) and an electronic system (including a computer), which may facilitate an interface between the mind (which makes persons aware of themselves, others, their thoughts and their consciousness) and cyberspace.

In this context, direct interfaces will be defined as those that enable an interaction between a neuronal network and an electronic system that does not require any traditional form of communication, such as the use of voice, vision or sign language.

At the very heart of this revolution in neuronal interface systems lies the computer. This is because computing power has increased exponentially over the last few decades and is certain to continue into the future. As a result, computing technology will invade the lives of nearly all *Homo sapiens* on the planet.

This means that new interfaces may provide fresh possibilities for human beings, enabling them to access new functions, information and experiences. As the Australian bioethicist Julian Savulescu indicates:

> [N]euroscience, together with computing technology, offers radical opportunities for enhancing cognitive performance. Already, chips have been introduced into human beings for purposes of tracking and computer-assisted control of biological functions. Minds are connected through the internet and there may be no barrier in principle to direct mind-reading and thought-sharing across human minds. Uploading of human minds to artificially intelligent systems represents one of the most radical possibilities for human developments.[1]

But questions may then be asked about the consequences on the lives of human beings of such a close association between humankind and machine-computers, as well as any resulting interface between the human mind and cyberspace. Would they, for example, enable individuals to really become 'hardwired' and 'programmed' to make certain decisions? In this regard, American neuroscientist James Giordano explains that these questions will quickly become more challenging and compelling when more integrated neuronal interfaces become possible, adding: 'But the time from first steps to leaps and bounds is becoming ever shorter, and the possibilities raised by the pace and breadth of this stride are exciting, and, I'd pose, equally laden with a host of concerns. It will be interesting to be part of this evolution.'[2]

Because of this, and although the consequences of neuronal interface technologies on society remain uncertain, a number of questions can already be presented on ethical, legal, political, economic, philosophical, moral and religious grounds. For instance, it will be possible to ask the following questions:

– Do neuronal interface systems belong to reality or fiction?
– Will a permanent link to vast amounts of information be beneficial or detrimental?
– Where does rehabilitation stop and performance enhancement begin?
– What are the risks relating to neuronal interfaces?
– When do invasive implants become justifiable?
– Can all the legal consequences from the use of such interfaces be anticipated and addressed?
– Can interfaces significantly change the very identity and personality of an individual?
– Could they be used to take away suffering?
– Will neuronal interfaces eventually lead to a redefinition of humanity?[3]

This book necessarily operates in a difficult territory since ethical considerations are intrinsically associated with what it means to be human and how society understands this concept of humanity – a task that has eluded most thinkers over the millennia.

Moreover, it is necessary to seek to better understand the concept of human identity in the context of the human person. This is because adding new capabilities to a person's mind by installing technology may well change his or her sense of self.

A person's perception of the benefit of a technology may, in addition, be affected by whether he or she remains in control or whether control is given over to something or someone else. In this regard, having a powerful system interfacing directly into a human brain may be too limited to be of concern, but may also enable possible external powers to have direct and abusive access to the inner being of a person.

It is indeed recognised that any form of new technology can affect the current dynamics of power. As the British technology commentator Guy

Brandon indicates: 'Technology always brings some value to the user and power over those who do not possess it.'[4]

Further questions can then be asked about what a human body or mind represents. As already mentioned, in the past a computer was generally something that was quite distinct from the human body that was relatively easy to define in both philosophy and law. With the development of direct interfaces between human bodies and computers, including devices that can be implanted inside the human brain, this will change. But what would this then mean for the person? Would the manner in which technology is applied to the body of an individual influence the way in which society considers this human being?

Some new interfaces, for instance, may enable human minds to escape the limitations of their human brains by combining with human computers to become cyborg-like fusions of machines and organisms.[5] The English biologist and science fiction writer Brian Stableford states:

> The potential is clearly there for a dramatic increase in the intimacy with which future generations of people can relate to machines. Machines in the future may well be able to become extensions of man in a much more literal sense than they ever have in the past. Working systems directed to particular tasks will one day be constructed that are part flesh and part machine, and the two will blend together where they interface.[6]

But would this then be good, bad, inevitable or to be avoided at all costs? How would such direct neuronal interfaces impact upon business, security, education, freedom and liberty of choice? Would, for example, new legislation need to be drafted and enacted?

It is because of all these questions as well as the possible ethical, philosophical and social challenges resulting from neuronal interfaces that this introductory book on human cyberneuroethics[7] was written in order to present some of the ethical challenges while providing a basis for reflection concerning a possible way forward. Indeed, an engagement with the profound implications of direct interfaces between the human neuronal system and the computer, as well as between the human mind and cyberspace, has become crucial. This is especially the case if society wants to engage with the future of humanity in a responsible, considered and effective manner.

Unfortunately, it is all but impossible to completely foresee the different developments of a technology and be in possession of all the relevant information. Moreover, one of the real difficulties of examining the ethical consequences arising from new biotechnologies is that they often develop very quickly. As a result, ethical considerations may lag far behind current technological procedures. This is the reason why any ethical discussion related to neuronal interfaces will be a dynamic and evolving endeavour making the preparation and drafting of regulations (such as the ones proposed in the Appendix) a continuous process with numerous re-evaluations.

In this context, the book will begin by exploring the existing situation in terms of what is already possible while considering future prospects and whether they are likely to help or harm. For instance, at present, neuronal interface systems considered for therapeutic purposes are, generally, seen as acceptable from an ethical perspective. If it becomes possible to read the brain pattern of completely paralysed persons so that they can use a computer, this would enable them to address some of their limitations, and the advantages may well outweigh the risks.

But when these therapeutic applications are transformed into possible enhancements, beyond what is considered to be normal, more ethical considerations about the proportionality between possible advantages and risks become necessary.

In order to study such future contexts, it is sometimes helpful to investigate the manner in which the technologies are already considered in society by examining, for instance, how the general public may understand or respond to popular fiction presenting the new developments. As such, fiction may be seen as a prophetic voice in this arena, asking the 'what if' questions through dystopian or utopian alternatives. In fact, connecting a person to a computer has often been a natural starting point for many science-fiction films and books, which can be useful in examining some of the possible consequences. But with new developments in technologies, more realistic fiction may now be required, since new possibilities have emerged. As the British engineer and neuronal interface pioneer Kevin Warwick explains:

> For many years science fiction has looked to a future in which robots are intelligent and cyborgs – a human/machine merger – are commonplace . . . Until recently however any serious consideration of what this might actually mean in the future real world was not necessary because it was really all science fiction and not scientific reality. Now however science has not only done a catching-up exercise but, in bringing about some of the ideas initially thrown up by science fiction, has introduced practicalities that the original storylines did not extend to (and in some cases still have not extended to).[8]

Cases of science fiction will thus be considered throughout the present study to examine some of the possible future challenges and advantages, while seeking to understand a number of the concerns that may already exist amongst the general public.

But it is also necessary to be wary since such science fiction may become, at one and the same time, more interesting but less careful as to future prospects. While there is huge value in exploring the 'not yet', it is important to do so cautiously before imagining opportunities that technology is unlikely to deliver, or at least not in the near future. This is emphasised by the French computer scientist Maureen Clerc and others, who explain that 'despite the enthusiasm and interest for these technologies, it would be wise to ponder if . . . [neuronal interfaces] are really promising and helpful, or if they are simply a passing fad, reinforced by their "science fiction" side'.[9]

This warning is very apposite since current neuronal interface devices are still unable to compete in terms of speed, stability and reliability with the standard interaction devices that already exist, such as a mouse or keyboard. But it is impossible to predict how things will develop and it would be irresponsible to just sit back and watch technology develop, believing that it is as inevitable as the tide and a natural force that cannot be restrained. This means that society should be prepared to anticipate new technologies with their associated advantages and risks. Ethical reflection should therefore be welcomed in its assessment of all the new possibilities direct neuronal interfaces can offer.[10]

In short, the challenge of cyberneuroethics is to develop some form of consistency of approach while preparing policies to regulate developments in an appropriate manner with the support of public opinion. As such, it is only the beginning of what is certain to be a very long and vast process lasting decades if not centuries.

Notes

1. Savulescu, 'The Human Prejudice and the Moral Status of Enhanced Beings', 214.
2. J. Giordano, interviewed by N. Cameron. Retrieved 23 February 2017 from http://www.c-pet.org/2017/02/interview-with-dr-james-giordano.html.
3. Bocquelet et al, 'Ethical Reflections on Brain-Computer Interfaces'.
4. Brandon, 'The Medium is the Message', 3.
5. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 7.
6. Stableford, *Future Man*, 171.
7. The term 'cyberneuroethics' is a neologism that was briefly used, for the first time, by the American legal academic Adam Kolber on the *Neuroethics & Law Blog*. Retrieved 9 October 2018 from http://kolber.typepad.com/ethics_law_blog/2005/12/cyberneuroethic.html.
8. Warwick. 2014. 'A Tour of Some Brain/Neuronal-Computer Interfaces', 131.
9. Clerc, Bougrain and Lotte, 'Conclusion and Perspectives', 312.
10. Ibid.; Schneider, Fins and Wolpaw, 'Ethical Issues in BCI Research'.

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Chapter 1

Why Use the Term 'Cyberneuroethics'?

In order to examine why the term 'cyberneuroethics' was developed in this book, it may be useful to present a brief overview of the manner in which each component of the cyberneuroethics triad is used in order to provide clarity before exploring how they interact together. For example, it is easy to talk about connecting a computer to a nervous system without emphasising whether the point of contact will be the brain, the spinal cord or the peripheral nerves. Indeed, each would have quite different implications.

In this regard, the prefix 'cyber' and 'neuro' will first be studied before examining the manner in which 'neuroethics' is presently defined in bioethics and why the term 'cyberneuroethics' was finally chosen.

The 'Cyber' Prefix

It was the French physicist and mathematician André-Marie Ampère (1775–1836) who first mentioned the word 'cybernétique' in his 1834 *Essai sur la philosophie des sciences* to describe the science of civil government.[1] However, the original term of cybernetics came from Ancient Greek, where it reflected the notion of a 'steersman, governor, pilot or rudder', while including notions of information, control and communication.

The term 'cybernetic' was also borrowed by the American mathematician and philosopher Norbert Wiener (1894–1964) and colleagues, who examined how communication and control could be examined in animals, including humans, and machines.[2] Wiener published a book in 1948 foretelling a new future entitled *Cybernetics: Or Control and Communication in the Animal and the Machine*, which gave an intellectual and practical foundation to the idea of highly capable interconnected calculating machines.

In his introduction to this volume, Wiener describes a situation in which it is difficult to make progress without a pooling and mixing of knowledge and skills between the various established disciplinary fields. This is because:

> Since Leibniz there has perhaps been no man who has had a full command of all the intellectual activity of his day. Since that time, science has been increasingly the task of specialists, in fields which show a tendency to grow progressively narrower . . . Today there are few scholars who can call themselves mathematicians or physicists or biologists without restriction . . . more frequently than not he will regard the next subject as something belonging to his colleague three doors down the corridor, and will consider any interest in it on his own part as an unwarrantable breach of privacy.[3]

For Wiener, the loss incurred by this restriction of knowledge was tragic, since the most fruitful areas of enquiry lay at the boundaries of different disciplines, which could only be explored by enabling two or more different sets of expertise to come together.

Eventually, the Second World War created an impetus and funding stream that enabled Wiener to draw together specialists who normally would not have interacted, enabling them to share their skills. But it was not long before the team realised that it was creating a new world that needed a new name. In this Wiener indicated that he had already become aware of 'the essential unity of the set of problems centering about communication, control, and statistical mechanics, whether in the machine or in living tissue . . . We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the same "Cybernetics"'.[4] The interdisciplinary technology of cybernetics was thus born, which included the study of information feedback loops and derived concepts.

Wiener was actually convinced that these feedback loops were necessary for the successful functioning of both living biological organisms and machines. This was because they enabled self-regulating and self-organising activities through a continuous updating of information given to the machine or organism with respect to variables such as their environment. In addition, he suggested that since both machines and living organisms equally relied on such feedback processes, they could actually be combined to create a new entity or creature.[5]

Cybernetics also focused on the manner in which anything (digital, mechanical or biological) processed information and reacted to this information, as well as the changes that were necessary to improve these tasks.[6]

The power of this control and communication theory was immense and, over the years, the term 'cyber' began to extend to all things representing a combination or interchange between humans and technology. In this way, the term started to evolve in many different settings where interactions were possible with electronic applications. This included everything from cybercafés to cyberdogs and from cyberwarfare to cybersex. How far Wiener could see into the future is difficult to say, but it would have been an adventurous mind that could envision the present concept of cyberspace.

Cyborg

With the concept of cybernetics being defined, as already noted, by Wiener and his colleagues, the term 'cyborg' was originally coined, as its close cousin, by the Austrian research scientist Manfred Clynes and the American research physician Nathan Kline (1916–1983) in 1960 as a combination of 'cybernetic and organism'. This included an enhanced individual with both human and technological characteristics.[7] Thus, any living being which was merged with neuronal interfaces was considered to be a cyborg.

In this regard, the notion of humanity being enhanced by technology has stimulated the imagination of the public since the 1920s. The British Broadcasting Corporation (BBC) television science-fiction drama series *Doctor Who*, which is one of the oldest in the world, was quick to pick up on the theme when, in 1963, the 'Daleks' were conceived. These were genetically modified humanoids from another planet, who had been integrated into a robotic shell while being modified to no longer experience pity, compassion or remorse.

From the 1970s onwards, cyborgs became popular in many other films, where they figured as invincible humanoid machines demonstrating no emotion. Some were visibly indistinguishable from humans, though others were more mechanical than human, such as with 'Darth Vader' from the 1977 film *Star Wars* created by George Lucas. Other examples are the 'Cybermen' introduced in the 1966 *Doctor Who* series. This brand of super-villains was created by degenerating humanoid beings, whose body parts were replaced with plastic and steel as a means of self-preservation. But because their humanoid brains were retained, 'emotional inhibitors' had to be inserted so that the new Cybermen could cope with the trauma and distress of their transformation. Yet at the same time, this meant that they could no longer understand the concepts of love, hate and fear.

Interestingly, cyborgs are often portrayed in popular culture as representing hybrid figures who overlap boundaries where existing familiar, traditional categories no longer exist. As such, they are often used to create narratives of apprehension about possible future technological developments, while raising questions about what human nature, identity and dignity actually mean. On this account, the cyborg expresses both the unease resulting from the perceived negative consequences of technology, and the sense of bewilderment and wonder before the extent and dominance of human technological achievement.[8]

One example of some of these anxieties may be considered when cyborgs are portrayed as being controlled by their technology to the detriment of their humanity and dignity. They are then presented as a kind of solitary monster, bringing disorder between the clear existing boundaries of what is human and what is machine. In fact, the Latin root of the word 'monster' is made up of *monstrare* (to show) or *monere* (to warn or give advice). As the American theologian Brian Edgar explains: 'Cyborgs – human-machines – are thus seen, perhaps more intuitively than anything, as both dehumanising and a threat to the order of the world. The idea produces existential feelings of insecurity and disorder as though the structure and fabric of society was under threat.'[9]

As such, cyborgs may play a similar role to the human-nonhuman mythological monsters of antiquity, such as the Chimera and the Minotaur, which were also considered as bringing disorder between the human and nonhuman boundaries. Because of this, these monsters were even considered dangerous and malign, necessitating destruction.[10]

But this kind of thinking did not stop in ancient history, since even during the Enlightenment, a number of scholars believed that the concept of monstrosity served as a moral boundary-marker. As the British social scientist and theologian Elaine Graham indicates: 'Monsters stand at the entrance of the unknown, acting as gatekeepers to the acceptable . . . the horror of monsters may be sufficient to deter their audience from encroaching upon their repellent territory.'[11] More generally, she argues that monsters serve a special function, which is neither totally beyond the bounds of the human nor conforming completely to the norms of humanity. In this way, they characterise but also subvert the boundary limits of humanity. She notes:

> Their otherness to the norm of the human, the natural and the moral, is as that which must be repressed in order to secure the boundaries of the same. Yet at the same time, by showing forth the fault-line of binary opposition – between human/non-human, natural/unnatural, virtue/vice – monsters bear the trace of difference that destabilizes the distinction.[12]

The American science and technology scholar Donna Haraway wrote an essay entitled *A Cyborg Manifesto* in 1983. This was prepared to encourage women to move the boundaries that appeared to be limiting their autonomy and as a response to the American politics of the day that explored and criticised traditional ideas about feminism. In this respect, Haraway explains that the breakdown in boundaries since the twentieth century enabling the concept of a cyborg to be explored included a disruption of the borders between: (1) human and animal; (2) machine and human; and (3) physical and nonphysical. In this, she uses the concept of the cyborg to illustrate the possibility that no real distinction exists between human beings and human-made machines.[13]

Therefore, the prospect is for humanity to increasingly question what it means to be human when the traditional boundaries are challenged. As the British philosopher Andy Clark explains, in the future 'we shall be cyborgs not in the merely superficial sense of combining flesh and wires but in the more profound sense of being human-technology symbionts: Thinking and reasoning systems whose minds and selves are spread across biological brain and nonbiological circuitry'.[14]

This would then require a significant reappraisal of the way in which human beings consider themselves and relate to others. In this regard, Clark indicates that human beings may already be natural-born cyborgs in that they have a capacity to fully incorporate tools even as simple as a pen and notebook as well as cultural practices which are external to their biological bodies. He also suggests that human minds are already conditioned to integrate non-biological resources enabling them to think through technologies.[15]

Cyberspace

First used in science fiction in the 1980s, the term 'cyberspace' now refers to the virtual space created as communication technology extends into settings such as offices, schools, homes, factories, trains and refrigerators. More specifically, the concept of cyberspace became popular in the 1990s when the Internet, which is an interconnected network between several billion computers around the world, and digital networking were growing exponentially. The term was able to reflect the many new ideas and developments that were emerging at the time.[16]

Cyberspace was also popularised through the work of American-Canadian science-fiction author William Gibson and became identifiable to anything related to online computer networks.[17] But he has now criticised the manner in which the term is understood, indicating, with respect to the origins of the word in 2000: 'All I knew about the word "cyberspace" when I coined it, was that it seemed like an effective buzzword. It seemed evocative and essentially meaningless. It was suggestive of something, but had no real semantic meaning, even for me, as I saw it emerge on the page.'[18]

The concept of cyberspace has therefore developed on its own and now denotes a global network of social experiences where persons can interact through, among other things, exchanging ideas, sharing information, providing social support, conducting business, directing actions, creating artistic media, playing games and engaging in political discussion. But while cyberspace should not be confused with the Internet, the term has slowly been transformed to reflect anything associated with online communication. A website, for example, may be said to exist in cyberspace, which is a space that cannot actually be characterised. Cyberspace thus represents the flow of digital data through the network of interconnected computers and is not 'real' in any three-dimensional sense, since it is impossible to spatially locate it as a tangible object. In this way, the term never really reflected a spatial concept as such, but rather described a network. Moreover, since cyberspace is the site of computer-mediated communication, in which online relationships and alternative forms of online identity are enacted, it is not just the place where communication takes place, but is also a social destination.[19] In other words, the concept of cyberspace does not simply refer to the content being presented, but also to the possibility for a person to use different sites, with feedback loops between the user and the rest of the system, enabling new developments for the user.

The American science fiction author Bruce Sterling explains:

> Cyberspace is the 'place' where a telephone conversation appears to occur. Not inside your actual phone, the plastic device on your desk. Not inside the other person's phone, in some other city. The place between the phones . . . this electrical 'space' . . . has flung itself open like a gigantic jack-in-the-box . . . This dark electric netherworld has become a vast flowering electronic landscape. Since the 1960s, the world of the telephone has cross-bred itself with computers and television, and though there is still no substance to cyberspace, nothing you can handle, it has a strange kind of physicality now. It makes good sense today to talk of cyberspace as a place all its own.[20]

Popular examples of persons being able to enter into cyberspace include the 1982 American science fiction film *Tron*, written and directed by the U.S. film director Steven Lisberger and based on a story by Lisberger and U.S. author Bonnie MacBird. In this film a computer programmer is transported inside the software world of a mainframe computer, where he interacts with various programs in his attempt to escape and get back out.

Another example is the 1999 film entitled *The Matrix*, directed by the American Wachowski siblings, which depicts a dystopian future where reality, as perceived by most humans, is actually a simulated reality called the Matrix created by sentient machines to subdue the human population. This is done in order to use their bodies' heat and electrical activity as a source of energy.

The 'Neuro' Prefix

The prefix 'neuro' originates from the Greek for neuron or nerve, which is related to the Latin *nervus* and has become popular in the last few decades to reflect something related to the brain and the nervous system. For example, the neurosciences form a multidisciplinary umbrella group in which each part unpacks some aspect of the way in which the brain and nerves operate. These include physical and biological sciences, behavioural and social sciences, clinical research, engineering and computer science, as well as mathematics and statistics.[21] In other words, the neurosciences examine aspects such as neurology, neurosurgery and neuro-oncology, with all the disorders relating to areas of the nervous system fitting under the frame of neuropathology.

But the 'neuro' prefix can also be used to express the manner in which the brain is sometimes used to understand other disciplines or ideas. This is why modern neurosciences are beginning to study the manner in which humans:

– use language and imagination to influence perceptions of time and space;
– perceive themselves and others;
– relate to other nonhuman living beings and to the natural environment;
– create from different historical, cultural, political, legal, economic and technical perspectives;
– acquire knowledge about themselves and the world; and
– produce and exchange things.[22]

From this perspective, neuronal modifications can be used for at least three purposes:[23]

– To maintain or improve mental health and cognitive function within typical or statistical norms.
– To address and treat disorders in order to achieve or restore typical or statistically normal functioning.
– To enhance function above typical or statistically normal ranges.

However, the neurosciences cannot answer on their own the significant ethical and anthropological questions that are important to society, such as what it means to be a morally responsible or free human being. But they can provide evidence for further reflection while supporting a better understanding of the functioning human brain, which may steer society's consideration of these questions.[24]

More recently, the prefix 'neuro' has also been added somewhat loosely to other terms that are not always easy to define, such as neuro-management,[25] neuro-fuzzy[26] and neuro-web design.[27]

Ethics

Ethics is the study of the values of human conduct and of the rules and principles that govern them. It seeks to distinguish what is considered to be good as well as ways of implementing these rules. Ethical considerations also seek to investigate the proportionality between the advantages and risks of a certain procedure, while examining whether it is possible to find an acceptable balance between the two. Sometimes, of course, it is difficult to define exactly what is meant by 'ethics' and even experts disagree. Generally, however, it refers to the study of standards of behaviour governed by what is agreed to be acceptable or correct. In this way, ethics examines and investigates moral choices, since morality refers more specifically to actual decisions and actions.

Ethical discussions have always been difficult because of the multiple ethical frameworks that exist, many of which argue from very different precepts and worldviews. In addition, few people currently adopt just one worldview while ruling out all other ways of thinking. This means that when facing a moral dilemma, most people usually pick and mix from the available options. Because of this, when a committee discusses an ethical dilemma, the issue often grows bigger with every additional participant. Each person is liable to have his or her own idea about which ethical approaches should be used at a given time and reaching a consensus can be well-nigh impossible. But if one is able to understand the principles underlying each mode of thinking, it is feasible to look at the outcome and ask questions about what led each person to that conclusion. This then strengthens the level of intellectual debate and, in theory at least, supports the development of more robust decisions.

In this regard, much of the so-called ethical debate occurring in modern media seems to operate at a level of descriptive ethics where stories are presented about the way in which people live and the choices they make. Through this, it is possible to gain a sense of where people place personal moral boundaries. However, the danger with this form of ethical debate is that it may imply a level of moral authority without actually explaining or even discerning the basis on which individual judgements are made.

In order to develop a better understanding, it is useful to examine the way people live, the choices they believe should be made and the values or worldviews they hold dear. From this perspective, it is possible to derive a sense of what they believe should normally take place. As a result, such 'normative ethics' can have a powerful effect on establishing moral frameworks within a society.

Like many disciplines, ethical concepts and principles also become more complex the more they are examined, which then introduces the concept of 'meta-ethics'. This questions the foundational thinking that is brought to any debate, making it feasible to even consider the meaning of the words being used, the nature of language and the way in which statements can be seen to be true or false. The following questions then become meaningful:

– What does it mean to say that something is right or wrong?
– Are there any objective criteria by which it is possible to assess moral statements?
– What is moral discourse? Is it a statement of facts or more than that?
– In what sense can a moral statement or position be said to be either true or false?

From this perspective, it could well be that ethical discussions may eventually prove inappropriate in giving absolute answers, but they do help in developing ethical theories and principles that can be useful in supporting discussions and public policy.

Neuroethics

The American author and journalist William Safire (1929–2009) is widely credited with giving the term 'neuroethics' its present meaning when, in 2002, he defined it as 'the examination of what is right and wrong, good and bad about the treatment of, perfection of, or unwelcome invasion of and worrisome manipulation of the human brain'.[28]

In other words, the interdisciplinary field of neuroethics generally refers to the ethical, legal and social impact related to neuroscience, neurology and neurotechnology.[29] This includes the manner in which neurotechnology, and an understanding of brain function, can be used to predict or alter human behaviour or change identity, as well as the implications for society. For instance, basic research in neuroscience is continuing to expand society's understanding of the biological basis of the brain's functioning and what this means for the mental, psychological and behavioural characteristics of a person.

This then raises new ethical and philosophical challenges with respect to the implications of these results and how they should be interpreted and used.[30] For example, the manner in which human beings understand themselves and other persons as 'neurological subjects'[31] is certain to affect the way in which individuals understand themselves and their relationships with others.

Difficulties and urgent questions also arise relating to the way in which society should make use of the knowledge obtained in neurobiology and the new applications emerging in this area with regard to healthcare provisions, legislative requirements and even political or social regulations.[32]

In 2013, the UK's Nuffield Council on Bioethics published its report *Novel Neurotechnologies: Intervening in the Brain*, which addressed the possible benefits and unintended consequences of intervening in the brain. It proposed an ethical framework to guide the practices of those involved in the development, regulation, use and promotion of novel neurotechnologies.

Likewise, the U.S. *Presidential Commission for the Study of Bioethical Issues* devoted some of its resources between 2014 and 2015 to explore societal and ethical issues raised by the government's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative,[33] which was financially supported to the tune of approximately $100 million in 2014 alone, with the primary goal of mapping the brain.[34]

In this respect, the U.S. Presidential Commission acknowledged in 2015 that the ethical questions arising from new neurotechnologies did need to be examined, even though it accepted that: 'Altering the brain and nervous system is not inherently ethical or unethical.' However, it did recognise that: 'Ethical assessment of neural modification requires consideration of who is choosing the modifier, what is being chosen, what its purposes are, who stands to benefit, and who might be harmed.'[35]

Some neuroethical questions are not very different from those often encountered in bioethics in general such as the challenges involved in participating in neurological research or questions relating to risks when new technologies are being applied. But others are unique to neuroethics, since any change to the brain, as the organ supporting the mind, may have broader implications relating to free will, moral responsibility, the nature of consciousness and personal identity.[36]

Neuroethical challenges and social consequences arising from the new neurosciences, together with all their consequences, will also demand careful consideration with regard to policy-making and government in the manner in which society may respond to these changes to protect public interest.

Cyberneuroethics

From the above definitions, cyberneuroethics can be characterised as the study of neuroethical challenges arising from a direct neuronal interface with a computer network and the resulting association that may develop between the human mind and cyberspace. This means that it will include some of the neuroethical questions arising from brain–computer interfaces and cyborg minds.

At this stage, and because of the pace of technological development, the interdisciplinary study of cyberneuroethics may have to be initiated despite the reality that many neuroethical and neuroscientific questions remain to be answered and developed. This is indeed one of the challenges of examining an ever-changing and expanding technology.

A significant number of cyberneuroethical issues will also reflect the manner in which a person's mind may integrate the information available in cyberspace and the way in which a person may be immersed in, and absorbed by, virtual reality. This is a reality that can be defined as immersive multimedia or computer-simulated sensory experiences, such as sight and hearing, and replicates an environment that simulates a physical presence in the real or imaginary world while letting the user interact in that world. Virtual reality can also characterise the 'place' where the cybernetic principle of a continuous organising and reconfiguration of information is present. In other words, it represents a fluid realm where boundaries and new possibilities may be changing all the time.[37]

With the development of cyberspace and a growing number of human beings deciding to spend an increasing amount of time in this virtual setting, many new opportunities and powerful experiences will be available to individuals. Being in virtual reality may then become more satisfying and rewarding for many individuals than genuine reality and could even become a preferable venue for them in which to construct and develop their identity.

However, in this cyberspace, the nature of moral agency and conduct may need to be redefined since it is possible to enquire whether common principles, values and rules are different between real and virtual realities or even between different virtual realities. It is thus possible to ask, as does the American ethicist Brent Waters, whether 'moral principles, values and rules make much sense within a realm of temporary borders and fluid boundaries?'[38]

What may eventually be considered ethical by examining what can be considered as good or bad behaviour in this virtual world existing in cyberspace is one of the main aspects of cyberneuroethics. But this implies that a person is able to make a choice between right and wrong, which requires a level of self-awareness, meaning that he or she has a mind supported by a brain or some other physical support.

It follows that cyberneuroethics will have to take account of the external effects that may influence the mind and brain of a person and how both of these interact when a person is seeking an experience in cyberspace.

The Terminology Being Used

In the context of the ethical debate relating to neuronal interfaces, many discussions note the difficulty of establishing clear borders between paired terms such as 'healing' and 'enhancement' or 'ability' and 'disability'.[39] Some even question whether it is actually meaningful to make a distinction between such terms.[40] Indeed, healthcare is often seen as being more than just treating disorders, which means that some procedures may occupy a grey area.[41]

It is also difficult to consider the concept of enhancement without understanding what is meant by the concept of 'normal'. As a result, it may be useful to try to characterise the different terms and the questions they raise in the context of cyberneuroethical discussion in order to inform the conversation in the twenty-first century and beyond. But because agreed definitions of the following terms seem impossible to obtain for the foreseeable future, only a regular redefining and updating of what these terms actually mean, based on common practice, may be feasible.

Enhancement (or Augmentation)

Enhancement can be defined as an activity (whether biological or not) through which an object or subject is transformed to exceed what is normal in order to improve its natural state or function.[42] For example, human enhancement has been defined by the U.S. President's Council on Bioethics in 2003 as 'the directed use of biotechnical power to alter . . . the "normal" workings of the human body and psyche, to augment or improve their native capacities and performances'.[43]

In other words, the concept of enhancement reflects the idea of using technology and science to increase the human functioning of a healthy individual beyond the norm for that person and in the absence of any identified dysfunction.[44] However, the concept does not generally include the creation of capacities in new beings that have never previously existed in humans (which may be considered under the concept of transhumanism). The aim is to improve upon the norm, but not to surpass a pre-existing, human, natural state or capacity. This means that enhancement procedures are not geared towards exceeding the achievement potential of human beings who are at the upper end of the statistical distribution. In this context, a cognitive enhancement was defined by the Swedish philosopher Nick Bostrom and the computational scientist Anders Sandberg as 'the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems'.[45]

Therapy versus Enhancement

As previously noted, distinguishing 'therapy' from 'enhancement' is difficult and would depend on the definitions of other terms as well as cultural norms and values.[46] Generally, however, therapy is associated with maintaining, treating or restoring body parts or functions that the patient previously possessed or enjoyed. A medical intervention is considered to be therapeutic when it restores human functioning to species-typical norms or gives abilities integral to the body that are considered to be normal. A therapy thus counteracts a known or an anticipated health deficit.[47] For example, kidney dialysis is a therapy that enables dysfunctional kidneys to filter impurities from the blood in a manner that approximates the properly functioning kidneys of a human being. However, an alteration of the brain that adds forty IQ points would be considered an enhancement if performed on someone who already has a normal IQ.[48]

This also means that if a society willingly seeks to enhance its members, then what would be considered normal for this community would eventually change. Previously normal traits could even be considered as dysfunctional if they no longer attain the new 'norm'. In such an event, these new dysfunctions could begin to be considered for treatment.

Notes

1. Tsien, *Engineering Cybernetics*, Preface, vii.
2. Hayles, *How We Became Posthuman*, 7.
3. Wiener, *Cybernetics*, 2
4. Ibid., 11.
5. Hook, 'Cybernetics and Nanotechnology', 53.
6. Kelly, *Out of Control*.
7. Clynes and Kline, 'Cyborgs and Space'.
8. Garner, 'The Hopeful Cyborg', 87–88.
9. Brian, *God, Persons and Machines*.
10. MacKellar and Jones (eds), *Chimera's Children*.
11. Graham, *Representations of the Post/human*, 53, quoted in Messer, *Respecting Life*, 135.
12. Graham, *Representations of the Post/human*, 54, quoted in Messer, *Respecting Life*, 135–36. See also Braidotti, 'Signs of Wonder and Traces of Doubt', 141.
13. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith', 713–16.
14. Clark, *Natural-Born Cyborgs*, 3.
15. Clark, *Natural-Born Cyborgs*.
16. Strate, 'The Varieties of Cyberspace', 382–83.
17. Thil, 'March 17, 1948: William Gibson, Father of Cyberspace'.
18. Documentary Film made by Mark Neale: *No Maps for These Territories*, 2000; Thil, 'March 17, 1948: William Gibson, Father of Cyberspace'.
19. Graham, 'Geography/Internet'.
20. Sterling, *The Hacker Crackdown*, Introduction.
21. Presidential Commission of the Study of Bioethical Issues, *Gray Matters*.
22. Secretariat of the EGE, European Group on Ethics in Science and New Technologies to the European Commission, *Ethical Aspects of ICT Implants in the Human Body: Opinion No. 20*, 5.
23. Presidential Commission of the Study of Bioethical Issues, *Gray Matters*, vol. 2, 3.
24. Ibid., 104.

25. Braidot, *Neuromanagement*.
26. Jyh-Shing, *Neuro-fuzzy and Soft Computing*.
27. Weinschenk, *Neuro Web Design*.
28. Safire, 'Our New Promethean Gift'.
29. Illes and Raffin, 'Neuroethics'; Farah, 'Neuroethics'.
30. Chan and Harris, 'Neuroethics', 77–78.
31. Cunningham-Burley, 'Engaging with Neuroscience'.
32. Chan and Harris, 'Neuroethics', 77–78.
33. U.S. Presidential Commission for the Study of Bioethical Issues, 'President Announces $100 Million Investment into BRAIN Initiative'.
34. White House, 'BRAIN Initiative'.
35. Presidential Commission of the Study of Bioethical Issues, *Gray Matters*, vol. 2, 3.
36. Chan and Harris, 'Neuroethics', 77–78.
37. Waters, *From Human to Posthuman*, 52.
38. Ibid., 53.
39. Grunwald, 'Human Enhancement'.
40. Parens, 'Is Better Always Good?', s1; see, for example, Norman Daniels' position discussed in ibid., s2.
41. Nuffield Council on Bioethics,*Novel Neurotechnologies*, 165; Parens, 'Is Better Always Good?'; World Health Organization, *Definition of Health.*
42. Moore, *Enhancing Me*.
43. President's Council on Bioethics, *Beyond Therapy*, 13.
44. Harris, *Enhancing Evolution*. Cf. British Medical Association, *Boosting Your Brainpower*, 9.
45. Bostrom and Sandberg, 'Cognitive Enhancement', 311.
46. For some, an intervention may be a therapy, but for others the same intervention may be a clear enhancement, leaving a grey area in between. Moreover, it can be unclear whether therapies, whose primary purpose is curing diseases, but that have a secondary potential of improving performance, should be classed as enhancements or treatment.
47. British Medical Association, *Boosting Your Brainpower*, 5.
48. Mitchell, 'On Human Bioenhancements', 133.

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Chapter 2

Popular Understanding of Neuronal Interfaces

At this stage, it may be useful to seek to examine how the general public may consider the possibilities arising from neuronal interfaces and how it is developing its views. This is important in framing the cultural setting of any ethical discourse, though it should be noted that public opinion generally only reflects the cultural values of large sections of a society and at a particular point in time. Moreover, the actual content of societal values may reflect a whole spectrum of attitudes towards science, technology and medicine.

In this respect, while many people may be ready to accept the benefits of modern technology and there is generally no generic public distrust of science, concern usually exists relating to the risks and dangers that may accompany specific developments. There is a fear that no one may be really 'in control' or 'knows what will happen' and doubts remain about the amount of trust to be given to governments in actually preventing or controlling potential lasting negative consequences.

In addition, a negative emotional reaction amongst the general public may exists towards certain technologies that should not simply be dismissed, in ethical considerations, as irrational or sentimental concerns. Rather, such a response may reflect an underlying but inarticulate social intuition. Moreover, if people feel an emotional reaction towards a procedure, this may be important and relevant to the moral positions, deeply held beliefs and intuitions of a society.

The English philosopher Mary Midgely warns against thinking of feelings as though they had no rational object or of considering the concept of reason as though it was, or should be, unaccompanied by feelings. If some persons seriously believe something to be wrong, then strong feelings will generally accompany that belief. Emotional reactions may be appropriate or they may be inappropriate, and to decide which '[w]e must spell out the message of the emotions and see what they are trying to tell us'.[1]

However, a spontaneous reaction can also be exploited for many different purposes, including its 'entertainment value'. As already noted, this already happened in modern science fiction treatments, which may then influence the general public, to varying degrees, towards their perception of new technology.

But media commentators such as Adam Keiper regret that novels and films on neuronal interfaces do not always represent scientific reality. He explains that 'public understanding of this research is shaped by sensationalistic and misleading coverage in the press; it is colored by decades of fantastical science fiction portrayals; and it is distorted by the utopian hopes of a small but vocal band of enthusiasts who desire to eliminate the boundaries between brains and machines'.

However, Keiper also recognises that this is not something new.[2] For example, many scientists may now regret the influence of English novelist Mary Shelley's (1797–1851) classic novel *Frankenstein*, published in 1818, about the existential trauma of a living monster created from the body parts of the deceased. However, the Frankenstein story may still have a place in the context of debate about changes to humanity since it seeks to explore, express and represent some of the revulsion, anxieties and emotions relating to crossing biological boundaries. It also portrays the frightening prospects of what can go wrong when scientists, working in secret and without any ethical oversight, end up creating new beings that can only be considered as 'monsters'.

The basis of the emotional reaction relating to some neuronal interfaces may similarly arise from the position that different biological and electronic elements should be kept apart, since mixed entities do not fit neatly into existing categories. From this perspective, human-computer cyborgs that cannot be clearly put into a specific category are usually considered as monstrous not merely because of their hideousness (which is merely an aesthetic expression of a lack of wholeness), but because they are seen as bringing disorder to an ordered setting.

With respect to neuronal interfaces, an important distinction may also be related to the different types of interfaces used. Indeed, some may not be seen to be as threatening as others to the identity or species status of the resulting being.

Interestingly, it may be the external appearance of the neuronal interfaces that creates the most aversion amongst the general public in contrast to any combination of nonvisible internal organs. This is because the public would immediately be confronted with an inability to identify the significant visible species distinctions which are important for any classification of living beings. The entity would be a 'something-in-between' and may be deemed to have no place in ordered society. Such feelings are obviously heightened when one of the parts is human, since additional questions of identity, legal rights and psychological issues come into play.

In order to understand public reactions, it is also necessary to explore the fundamental differences that exist in philosophical worldviews. Thus, according to the materialist and reductionist worldviews, biological beings are just made up of several types of complex substances composed of molecules that are common to all species, the only differences between species being merely the result of minor changes in the ordering of these molecules. For instance, the difference between proteins from cattle and human beings could be completely described by compiling a catalogue of the genetic differences that code for the proteins.

This worldview does not accept the idea of qualitative breaks in nature that then looks rather like a well-blended soup. Within this paradigm, species differences are a matter of drawing an arbitrary line and are to some degree illusory and unreal.

Public Understanding in the Media

As already noted, in seeking to develop an ethical perspective relating to neuronal interface systems, it is important to comprehend how society may consider these new technologies by examining, for example, popular and societal views and understandings. This may be done through public discussions, but also by studying the way in which the public is confronted with neuronal interfaces, such as the manner in which popular science-fiction films and books are used to portray possible new future technologies. As the scientist and Church of England priest Justin Tomkins states:

> The fact that the impact of technology upon society is not determined by the technology itself but by its interaction with society means that novels and films provide a significant means of exploring these issues. What is required is not simply a scientific analysis of the technology but an imaginative exploration of human society and how our behaviour is affected by a changing technological context.[3]

But, as already mentioned, another benefit of science fiction is that it enables possible neuronal interfaces to be considered in the light of future ethical questions examining the advantages and risks of new technologies.

In the case of neuronal interfaces, this began with bestselling science-fiction books, including the 1972 novel written by the American Michael Crichton (1942–2008) entitled *The Terminal Man*. This recounts the story of a man with brain damage receiving experimental, computer-controlled electrodes in his brain designed to prevent seizures, but that he eventually abuses for pleasurable aims.

Concerns that new brain–computer interfaces could possibly be misused by a government or the military have also been examined. In the 1981 BBC serial *The Nightmare Man*, a futuristic mini-submarine is wired by a brain implant to its captain, who then turns to murder after having ripped out the implant.

However, perhaps the most prominent early science-fiction novels relating to brain–computer interfaces were written by William Gibson. In 1981 he published *Johnny Mnemonic*, which tells the story of a young data trafficker who has undergone an operation enabling him to have a large data storage system implanted in his head. This was then followed in 1984 by a novel entitled *Neuromancer*, which was the first to be characterised under the 'cyberpunk' genre, which is a subgenre of science fiction featuring advanced technological and scientific achievements. In the book, mercenaries are enhanced through the use of brain implants that are linked up through a 'matrix' (which is the first time the term is used in this context).

Gibson's writings initiated an explosion of similar books, films and other media exploring brain–computer interfaces, such as the 1989 role-playing game *Shadowrun*. His book *Johnny Mnemonic* was even made into a film with the same title in 1995, which was directed by Robert Longo. This story was also the basis of the 1999 film entitled *The Matrix* and its subsequent sequels.

Another example of neuronal interfaces being used in fiction is the 1989 Japanese manga illustrated series entitled *Ghost in the Shell*, written by Masamune Shirow (the pen name of Japanese manga artist Masanori Ota), which follows a fictional counter-cyberterrorist organisation in the mid twenty-first century.[4] Computer technology is so advanced that many members of the public have enhanced (augmented) cyberbrains allowing their biological brains to interface with various networks. It is even possible to transplant human brains into completely robotic bodies so that individuals have permanent access to cyberspace.[5] This gives them a vastly increased memory capacity, total recall and the ability to view another person's memories on external viewing devices, as well as to initiate telepathic conversation with other cyberbrain users. But this high level of interconnectedness also makes the brain vulnerable to attacks from highly skilled hackers, including those who will hack a person in order to completely control their will, change their memory and deliberately distort their subjective reality and experience.

This has now been developed in a number of films which use the possibility of human brains being hacked in the story, such as in the 2018 film *Upgrade,* directed by the Australian Leigh Whannell.

A further science-fiction novel in the dystopian and cyberpunk genres reflecting a surprising degree of accuracy in predicting future technological development, as well as the associated ethical and anthropological challenges, was written in 2002 by American Matthew Anderson entitled *Feed*.[6] It depicts a future where the 'feednet', which is a super-computer network (a sort of precursor of an advanced form of the Internet), is directly connected to the brains of about three-quarters of Americans through the means of an implanted device called a 'feed'. This enables individuals to mentally access vast digital knowledge databases, to experience shareable virtual-reality phenomena and to communicate telepathically. In this world, privacy and self-ownership are constantly being challenged to fit individuals into consumer profiles. It also raises questions concerning corporate power, consumerism, information technology and the forms of discrimination, as well as limitations, that may exist for those who do not have the latest versions of technology. Data mining that extracts information from large quantities of data and transforms it into an understandable structure for further use is also examined in the novel.

A final example is the cyberpunk-themed action-role-playing video game *Deus Ex* developed by the American company Ion Storm and published in 2000 by Eidos Interactive. The game addresses the nature and impact of human enhancement with regard to a wide variety of prosthesis and brain implants. With the third game in the series, *Deus Ex: Human Revolution*, which is set in 2027, players can access enhanced human characters including those with implanted neurochips to improve their abilities, such as processing speeds and spatial awareness. They can even have a brain–computer interface allowing other persons, in other locations, to control their actions. The game raises questions about the possible disadvantages that such a society may represent to those who object to being enhanced (or cannot afford it) and the eventual risks for such individuals of becoming completely disenfranchised.

The success of these games, books and films demonstrates that society is interested in, and aware of, some of the ethical concerns, risks and advantages related to neuronal interfaces and the consequences that this may have on mind–cyberspace interactions. They also suggest different (fictional) ways in which society may respond to, and assimilate, new developments that are important in trying to understand how real future societies may seek to balance the possible advantages against the perceived risks.

Notes

1. Migeley, 'Biotechnology and Monstrosity', 9.
2. Keiper, 'The Age of Neuroelectronics', 4.
3. Tomkins, *Better People? Or Enhanced Humans?*, 121.
4. This gave rise to several films, including the 1995 Japanese animated science-fiction film entitled *Ghost in the Shell* and directed by Mamoru Oshii.
5. Similar technology is presented in the 1987 American cyberpunk action film *RoboCop*, directed by Paul Verhoeven, in which the brain and part of the digestive system of a policeman, who was shot, are integrated into a robotic body to form a superhuman, law-enforcing cyborg.
6. Anderson, *Feed*.

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Chapter 3

Presentation of the Brain–Mind Interface

Before examining the manner in which neuronal interfaces may directly connect the mind and cyberspace, it is necessary to first study what these neuronal networks represent and how they function in the central nervous system, which includes the brain and the spinal cord.

The Central Nervous System

The central nervous system consists of the brain and the spinal cord, which are situated in the skull and vertebrae respectively. Both have easily described main structures, though in each case, the fine substructures are exceedingly complex. They are both also formed of neurons, which are cells that store, process and transmit information through electrical and chemical signals. These neurons comprise a central body from which emanate a number of long fibrous branches consisting of one axon and a number of dendrites. They are therefore spider-like with spindly filament extensions that branch out, repeatedly, to make contact with other parts of the same neuron or with other neurons. A network is thus formed of neuronal connections. All the nerves in the human body consist of a bundle of axons of many neurons conveying information to and from the central nervous system.

Glial cells are also present in the nervous system and act to support neurons by enabling important chemical and physiological reactions to take place producing a number of substances required for normal neurological functioning.

Information in the nervous system is coded as electrical-chemical messages and sent through chains of neurons, usually going in one direction, from the dendrites through the cell body and along the axon, which is then connected to a dendrite or cell body of a neighbouring neuron.

The very small interconnecting gaps between neurons are called synapses and occur at the point where one neuron touches another, and are the places where signals are transferred. When a neuron transmits a message to a neighbour, it initiates an electrical signal to the synapse, eliciting the release of a small package of chemicals. These chemicals travel across the microscopic gap between the two cells, triggering a shock wave through a pulse of voltage in the second neuron, which then moves down its extensions. The nature of the response depends on the types of cells and the types of chemicals released.

Neurons are usually specialised in different ways in order to fulfil specific tasks. The number, length and pattern of the extensions that develop from the cell, the connections these make with other neurons, the neurotransmitters that are released to the neighbouring cell and the surface channels of receptors all make a neuron very specific in its role.[1] This form of organisation of the neurons is the basis of a kind of regional specialisation of function and is believed to increase the speed of communication.[2]

The brain makes up the largest portion, is the major functional unit and is often referred to as the main structure of the central nervous system. The spinal cord, on the other hand, has certain processing abilities relating to, for example, spinal locomotion and process reflexes.

The Spinal Cord

The spinal cord is the main pathway supporting information between the brain and the peripheral nervous system. Extending from the base of the brainstem is a bundle of neurons making up nerve fibres reaching down through a protective channel in a person's spinal column. It is a major trunk route directing signals from the brain to the body and vice versa.

However, it would be a mistake to see the spinal cord as a passive conduit of information. Much of the basic functional control of a person's body is organised within the spinal cord protected by the bony spinal column, with a length of about 45 cm in men and 43 cm in women, made up of bones called vertebrae. Although the spinal column is somewhat flexible, some of the vertebrae in the lower parts of the column may become fused.

The Brain

The brain is the most complex organ in the human body and is protected by the skull against any outside interference other than the neurons in the spinal cord and the brainstem, as well as hormonal changes in the blood supply.[3]

It is the organ that most profoundly distinguishes human beings from other species, including other primates, and is an extremely complex network of neuronal structures supporting specific personal aspects and characteristics. These include an individual's identity, self-awareness and his or her capacity to reason and make meaningful relationships. This is why so much importance is attached to the human brain and to understanding the very grave concerns that are associated with any direct intervention on any of its parts.[4]

Structure of the Brain

At its peak, a human brain has around one trillion (10^{12}) neurons, each of which is capable of up to 10,000 interconnections with other neurons. This gives the human brain 10 quadrillion (10^{16}) possible connections, enabling, for example, a person to recognise any changes in his or her environment and communicate these variations to other neurons, thereby directing a bodily response. However, as a person becomes older, some of these neurons begin to die so that by adulthood, only about one quadrillion connections remain.[5]

As already mentioned, different functions of the brain are generally associated with distinct areas of this brain. This structure–function relationship occurs not only at the macro-scale, in which the areas are composed of hundreds of millions of neurons, but also at a neuronal micro-scale. As such, the functioning of the brain in terms of processing signals, storing memories and triggering actions is intrinsically associated with the one-to-one linkages formed between the neurons, the types of chemicals used to carry messages between the cells and the relative timings of the exchange of these chemicals. Given that there are billions of neurons, each of which makes tens of thousands of synaptic connections, the complexity of this network is massive.

It is possible to consider the brain as if it were a computer, with a binary 0 and 1 code driving the processing, but this is an inadequate comparison. Computers are, undoubtedly, highly capable and their power continues to expand exponentially. However, the brain's multi-layered complexity makes it a difficult organ to understand at an individual neuronal level. This means that it will take a long time for computers to begin to function at the same level. The pattern and strengths of connections continually change as a person meets new challenges and goes on to record and process each day's experiences. The change can also be dramatic. For example, brain injury where entire areas of the brain no longer function can restrict certain abilities, although after some time, these may begin to return as other areas of the brain seek to compensate. As such, the structure–function relationship can be seen as both necessary and plastic.

Function of the Brain

In 1824 the French physiologist Jean-Pierre Flourens (1794–1867) published the results of a series of experiments in which he removed certain portions of pigeons' brains to see what happened.[6] He found that removing a specific part destroyed the sense of will, judgement and perception of the birds, and that removing another part took away the animal's muscular coordination and its sense of balance. Finally, taking out a third part of the brain, which seemed to contain the cardiac, respiratory and vomiting centres, killed the birds.

On the other hand, Flourens was unable (probably because his experimental subjects had relatively primitive brains) to find specific regions for memory and cognition, which led him to believe that they were present in a diffuse form around the brain. This meant that different functions could generally be ascribed to particular regions of the brain, but that a finer localisation was not possible.

Neuroscientists can now examine the brain in many different ways. For instance, they can study the neurons themselves as the basic building blocks of brain function by examining the detailed biology of these neurons and how the transmission of information takes place. But researchers can also study the brain at a more general level by investigating the way in which neurons form circuits and networks of communication through electrical and chemical signalling, or even examine a certain activity as it takes place in a whole region of the brain.

This last approach can vary from a detailed analysis of a simple memory circuit to broader influences on the function of a human brain using more advanced measuring devices in a conscious human being. Alternatively, instead of examining the brain itself as a biological entity, it is possible to concentrate on the cognitive, social and behavioural consequences of brain function.

At present, most neuroscientists believe that it is necessary to combine these molecular, cellular and circuitry systems all together with cognitive approaches, while seeking to understand human behaviour and social interaction in order to obtain a more general understanding of brain function.[7]

The different parts of the brain include the following.

The Brainstem

The brainstem consists of an extension of the spinal cord with which its organisation and functional properties share similarities. It supports an entry and exit system to the brain for a number of communication pathways that influence elements such as breathing, balance, taste, hearing, the heart and blood vessels.

The Cerebellum

The cerebellum holds more neurons than any other part of the brain, including the larger cerebrum (see the next section), but consists of fewer different types of neurons. The cerebellum modulates the outputs of other areas of the brain to make them more specific. It represents about 10 per cent of the brain's total volume but contains 50 per cent of its neurons. If the cerebellum is removed in an animal, it can still perform most activities, but becomes much more hesitant and clumsy.

The function of the cerebellum includes posture and the coordination of movements of the eyes, limbs and the head. It is also involved in motion that has been learned and perfected through practice and will adapt to new learnt movements. Moreover, it displays connections to areas of the cerebrum that are important for language as well as cognitive functions.

The Cerebrum

The cerebrum (Latin for *brain*) is the largest single part of the brain in humans and is responsible for processing information, using more than 90 per cent of the oxygen supplied to the brain. It contains the cerebral cortex, which consists of two symmetrical parts (cerebral hemispheres) in the left and right part of the skull, between which there is a clear division.

The cerebral cortex is one of the most important parts of the human brain, with different specialised regions addressing motor, visual, auditory and olfactory functions, as well as those for high-level perceptual analysis of faces, places, other persons, learning, speech, cognition and emotional control.[8]

Cerebral cortex circuitry is extremely complex and neuroscientists are only just beginning to use new tools, such as neuroinformatics or network science together with more traditional biological examinations, to try and understand the functional connections within and between cortical regions.[9]

However, one important discovery in relation to the way in which human brains work is that there is no straightforward 'one-to-one' link between brain structures and mental processes, though particular brain areas associated with particular functions do exist. Many cerebral cortex regions have numerous integrating and analytical characteristics. This means that certain brain regions cannot be ascribed to a unique function. Instead, a particular brain structure may be associated with a number of mental processes, while particular mental processes may involve several brain areas.[10] For instance, a number of human experiences, such as the perception of pain, involve a spatial and temporal pattern of activity in multiple brain regions.[11]

Biological Development of the Brain

The brain continues to develop in a human person until about the age of twenty, during which time the wiring of the brain undergoes major changes that are dependent on environmental influences. When a person is born, the great majority of his or her neurons already exist and are in their final position in the brain, though many are still disconnected from one another. New connections are formed only after birth and continue until adulthood. These are then preserved or reduced depending on neuronal activity and any external factors that affect this activity. This means that every interaction with, for example, physical and societal environments as well as lifelong learning processes will influence the arrangement and structure of neuronal connections in the brain. It is believed that this happens as a result of existing connections being strengthened or weakened in relation to how much they are used. This implies that the neurological structure of a mature brain may be influenced by:

– genetic predisposition that determines the general structure of the brain;
– the cellular and physiological shaping of connections that modify the brain in relation to its environment during development;
– lifelong adjustments in response to different experiences.[12]

Many neurobiologists believe that all functions of the brain can be reduced to its structure and the connections between neurons, though it should be emphasised that every function is the result of widely distributed neuronal networks. Thus, for these scientists, the most complex functions of the brain can only be the result of what goes on in the brain. This includes basic functions such as the ability to perceive, remember and act, but also higher functions such as the ability to decide, control attention and generate emotions. Even the ability to understand and generate speech, to consciously deliberate and be self-aware as an independent, autonomous and intentional agent is believed to only be the result of brain structure, the connections between neurons and the signals that pass between these neurons.[13]

The Mind

In the seventeenth century, the French philosopher René Descartes (1596–1650) concluded that 'Cogito ergo sum' – 'I think, therefore I am', or possibly better translated as 'I am thinking, therefore I exist'. At the beginning of an age of observation-based discourse, thinking took on a whole new role, but it also posed a dilemma concerning the possibility of trusting what comes in through the senses. How does one know whether anything one sees, hears, tastes or encounters is real and not just an illusion?

Descartes' conclusion was that the only thing he could trust – the only reason why he knew he existed – was that he was aware of his own thoughts. In his 1638 *Discourse on the Method*, a study on proving self-existence, he indicated that a person would not be able to recognise whether an evil demon had trapped his or her mind in a black box and was controlling all its inputs and outputs.

In 1981, the American philosopher and computer scientist Hilary Putnam (1926–2016) presented a modern parallel to Descartes' argument in his 'brain in a glass vat' thought experiment, in which a human brain was removed from a person's body and suspended in a vat of life-sustaining liquid.[14] He suggested that if the same information from a computer imitating reality was given to a brain in the vat as was given to a brain in a normal human head, this brain in the vat would not know where it was situated. Moreover, it would not be able to distinguish deception from reality. The computer would be simulating reality in such a way that the 'disembodied' brain would continue to have normal conscious experiences, even though these never really happened in the real world.

The brain in the vat thought experiment is often used in philosophy to understand aspects of knowledge, reality, truth, mind and meaning. For example, since it is impossible to know whether a brain is in a vat or a human skull, it is impossible to determine whether most people's experiences are true or false. This then raises questions about how a person can know and be certain of anything.

In Descartes' time, the brain was poorly understood and life was believed to dwell in the blood. The English anatomist William Harvey (1578–1657) had demonstrated that blood circulated around the body, breaking with the historical belief that it ebbed and flowed from the heart. It was also difficult to disregard the critical observation that if the blood was left to pour out of a person, he or she would eventually die.

But the following 300 years saw a gradual shift from blood to brain, with mental reflection being seen as a key aspect of human life and existence. Death can now be defined, in many countries, in terms of an absence of critical brain function (brain death). The heart may still be functioning with a healthy blood flow, but if a person is considered to be brain dead, then physicians can decide that this individual has died.

It is therefore the possession of a functioning brain supporting a mind that seems to matter in modern society in terms of characterising whether a person is alive. However, a long history of philosophy, religion, psychology and cognitive science has been necessary to try to develop an understanding of what defines a mind and its essential properties. And although this is still an ongoing process, a useful definition of the mind in a human being can be characterised as the set of cognitive faculties that enables consciousness, awareness, perception, thinking, judgement and memory to exist.[15]

A mind also allows a person to attribute mental states to other persons, which enables each individual mind to recognise that others also have minds. This capacity begins to gradually develop in children between the ages of three and four, when they begin to understand that they and other persons also have minds.

A further question that can be considered is whether it is only human beings who possess a mind or whether it may be possible for a machine, such as a computer, to also have a certain kind of thinking mind enabling self-awareness. However, this raises the difficulty that it would only be the computer that would know that it existed since, using Descartes' formula, it is not possible to know for certain whether anyone else exists.[16]

The Brain–Mind Interface

By returning to Descartes, it is possible to suggest that human persons are composed of mental 'stuff' that is the basis of the mind that is living inside a body made of physical 'stuff'. In other words, Descartes suggested that the mind is found in an immaterial domain that he called *res cogitans* (the realm of thought). The domain of material things, on the other hand, he called *res extensa* (the realm of extension).[17] He then proposed that the interaction between these two domains occurred in a small midline structure of the brain called the pineal gland.

But while it is accepted that Descartes' explanation may be coherent, few present-day philosophers and other scholars are satisfied with his suggestions, especially with respect to the pineal gland.[18]

Nevertheless, the manner in which mental functions are enabled by the brain is still not fully understood. It is a question that has often been recognised as the Mind-Body dilemma for which many proposed solutions exist, which are generally divided into two broad categories, each with numerous variants:[19]

1. *Dualist solutions*: these keep Descartes' distinction between the realm of mind and the realm of matter, but they give different answers about how the two realms relate to each other, including the following:
   a. Substance dualism: where the mind is formed of a type of nonphysical substance that is not governed by the laws of physics. The brain, on the other hand, is considered to be a kind of physical substance. It also indicates that the two substances may interact with each other in causal relationships.
   b. Property dualism: where the laws of physics are universally valid, but cannot be used to explain the mind. In this way, the mind exists as a nonphysical entity representing a mere property of the physical brain (a sort of side-effect), but not a specific substance in itself.
2. *Monist solutions*: these postulate that there is only one realm of being. Mind and matter are both aspects of this realm. There are three main types of monism:
   a. Physicalism: where the mind consists of matter organised in a specific way.
   b. Idealism: where only thoughts exist and matter is an illusion.
   c. Neutral monism: where both mind and matter are aspects of a distinct essence that is not itself identical to either of them.

Even though neurobiological research has made a lot of progress in recent years, there are still no comprehensive models of this structurally complex and functionally dynamic system. Thus, the ancient debate about the actual relationship between mind and brain, and between mental and brain states, remains unresolved. As the U.K.-based ethicists Sarah Chan and John Harris indicate, 'despite modern scientific understanding of the brain, the philosophical relationship between brain, body, mind and identity remains elusive'.[20] However, it is taken for granted that a person's mental capacities, such as perception, thought, memory, feeling and agency, are dependent upon his or her brain.[21]

Another reason why the brain is crucially important is because of its key capacity to control a whole body. Indeed, the embodiment of a person is an essential characteristic of his or her existence, identity and capacity for perception and action. The brain is also central to the way in which a person interacts through language and emotion. Again, as Chan and Harris indicate: 'The inherently problematic nature of this can be explored through two related but conceptually distinct questions: "Am I my mind?", and "Is my mind my brain?" Clearly, "we" are not just our brains or our minds: our sense of identity is closely associated with our physical bodies; our experience of the world, though expressed in one form as brain activity, necessarily includes the phenomenon of embodiment.'[22]

As a result of neurological research, and especially from the information obtained from brain injuries, it is possible to show that this sense of self-awareness is also based upon non-conscious functions in the brain. These both prepare certain aspects of conscious thoughts while processing the human body's daily functioning, such as breathing and digestion. This means that non-conscious processes, in addition to conscious functions, make a contribution to the way in which persons understand themselves and others.[23]

However, this dependence on the physical brain of a person's sense of self and self-identity may give rise to further questions. For example, it is possible to ask whether an individual is still the same person if his or her brain changes quite significantly through, for example, injury, disease, surgery or even the passing of time. It may also be possible, in the near future, to examine how these changes affect the physical brain, but this may still not provide any final answers.[24]

In addition, the manner in which the mind, including the way in which a person experiences self-consciousness, is related to biology has very important implications to the understanding of free will and responsibility, which has direct consequences on cyberneuroethics. If all the decisions of a person can be reduced to neurobiology or a material basis, how can he or she be responsible for his or her choices and actions? Indeed, responsibility means that an individual has a free will to make another decision.

Would it then be possible, for instance, for persons to defend themselves in court by arguing that it was, in fact, their brains that made them commit a crime? From this perspective, a better understanding of neurobiology may completely change the manner in which free will and responsibility are considered.[25] But whether this may eventually happen remains an unresolved question.

It is also important to examine how external influences may affect the brain and thereby the mind of a person, and whether this would then influence the way in which a person makes decisions. As the North American ethicist Walter Glannon explains:

> [T]he mind emerges from and is shaped by interaction among the brain, body, and environment. The mind is not located in the brain but is distributed among these three entities as the organism engages with and constructs meaning from its surroundings. Our capacity for desires, beliefs, intentions, and emotions, and to deliberate, choose, and act, is grounded in the fact that we are embodied and embedded minds. We are embodied minds in the sense that our mental states are generated and sustained by the brain and its interaction with external and internal features of our bodies. We are also embedded minds in the sense that the content and felt quality of our mental states is shaped by how we are situated and act in the natural and social environment.[26]

This environment, for instance, includes the influences that may arise if the mind is fused with cyberspace through a direct neuronal interface appliance. Of course, such interfaces are relatively unsophisticated at present, but they will be considered in the following chapter in order to examine how information may be directly obtained and provided to the brain.

Notes

1. Bear, Connors and Paradiso, *Neuroscience*; Kandel et al., *Principles of Neural Science*.
2. Shipp, 'Structure and Function of the Cerebral Cortex'.
3. Bear, Connors and Paradiso, *Neuroscience*; Kandel et al., *Principles of Neural Science*.
4. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 73.
5. Moor, *Enhancing Me*, 54.
6. Flourens, 'Experimental Researches on the Properties and Functions of the Nervous System in the Vertebrate Animal', 129–39.
7. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 11.
8. Kanwisher, 'Functional Specificity in the Human Brain'.
9. Shipp, 'Structure and Function of the Cerebral Cortex'.
10. Poldrack, 'Can Cognitive Processes Be Inferred from Neuroimaging Data?'
11. Tracey, 'Imaging Pain'.
12. Singer, 'A Determinist View of Brain, Mind and Consciousness', 41–48.
13. Ibid.
14. See Putnam, *Reason, Truth, and History*, 222.
15. The *Oxford American College Dictionary* defines 'mind' as 'the element of a person that enables them to be aware of the world and their experiences, to think, and to feel; the faculty of consciousness and thought'.
16. Moor, *Enhancing Me*, 62.
17. Dy, Jr., *Philosophy of Man*, 97.
18. Lokhorst and Zalta (eds), 'Descartes and the Pineal Gland'.
19. Jaworski, *Philosophy of Mind*, 5–11.
20. Chan and Harris, 'The Biological Becomes Personal', 49–50.
21. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 73.
22. Chan and Harris, 'The Biological Becomes Personal', 49–50.
23. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 73.
24. Chan and Harris, 'The Biological Becomes Personal', 49–50.
25. Greely, 'The Social Effects of Advances in Neuroscience'.
26. Glannon, 'Our Brains are Not Us', 321, mentioned in Jotterand, 'Moral Enhancement, Neuroessentialism, and Moral Content', 48.

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Chapter 4

Neuronal Interface Systems

Part of the challenge faced by anyone seeking to seriously examine the ethical implications of applying neuro-based technology to cyber-based aspects of life is the pace of change of such technology. But it is also important to distinguish between what is fact and what is science fiction, or what on occasions is more a matter of future-fiction, given that the ideas are so incredible that they are unlikely to ever become reality.

Indeed, it is difficult not to be sceptical concerning the grand vision of greatly enhanced human cognitive abilities and the use of neuronal interface systems that have sometimes been presented. In addition, the suggestion that laptop computers are already more intelligent than insects needs to be qualified, since simply comparing neurons to computer capacity is inappropriate. As already mentioned, unfortunate comparisons have been portrayed between biological brains and computers. Moreover, the choice of analogies and language may reflect the implicit values and worldviews of the persons making such claims.

The way in which the neuronal system works is far more complex and efficient than silicon-based systems. In biological systems, the basic functioning unit is molecular or cellular. This is in contrast to electrons moving along a wire or in a semi-conductor. If connectivity is also taken into account, the brain is extremely intricate, with each neuron having direct connections with up to thousands of other neurons. Furthermore, the brain operates as a network based on interactions from external impulses, which means that if an activity is not maintained, it will slowly disappear.[1]

Over the past few years, however, new developments in information technology and a better understanding about how the human brain functions has enabled new ways in which communication interfaces between the brain and appliances, such as computers, can be considered.

Developments in Information Technology

When pictures of Apollo 11 were presented showing that humans had landed on the moon in 1969, the world held its breath and stood in awe as humanity congratulated itself on its technological brilliance. Human beings were amazed at what they could do in partnership with the technological world. The guidance system, in particular, could solve equations at unparalleled speed, with the processor being capable of performing around one million calculations a second. Using this, a millennia-old fantasy to go into space could be achieved.

At present, however, the numbers seem to come on a different scale. A standard laptop computer now performs billions of calculations a second and this is increasing annually. This means that developments in the way in which neuronal interfaces may find new applications, such as with ever more powerful computers, will also likely increase.

Moore's Law

By mapping out the progress in raw computing power onto a chart, it is possible to observe a phenomenon known as Moore's Law (though it is an observation and not a law). In 1965, the cofounder of the computer company *Intel Corporation*, American Gordon Moore, predicted that computing power would double about every two years. He also suggested that: 'Integrated circuits will lead to such wonders as home computers – or at least terminals connected to a central computer – automatic controls for automobiles, and personal portable communications equipment.'[2] Over the following decades, this predicted exponential growth appears to have been respected. The cost to the consumer has also plummeted on a similar basis.

Currently there seems to be no break in the trend, though there are signs that this line may not simply stretch out indefinitely. As companies have increased the technical functions that can be squeezed into a computer chip, development costs of each new aliquot of functionality has increased accordingly. Initially, it was relatively easy to double the power – now developments seem to be approaching the buffers as the components within a chip become atom-sized elements. A probable limit could be reached between 2020 and

2040, though this may be cirumvented in new forms of computers. For example, research teams are already examining whether it may be possible to harness living neurons as a means of packing more information into a very small space.

The Internet

Another development that has taken place in parallel to the expansion of computers is the Internet, which is a network of networks formed of private, public, academic, business and government computers linked by a broad array of electronic, wireless and optical technologies. The Internet supports an extensive range of information resources and services, such as the applications of the World Wide Web, which is an information space where documents and other web resources can be identified, interlinked and accessed.

The Internet was originally developed through research commissioned by the U.S. government in the 1960s with the aim of building strong, fault-tolerant communication via computer networks. The subsequent interconnection of regional academic systems in the 1980s then marked the beginning of the transition to what is now known as the Internet. This grew exponentially when numerous institutional, personal and mobile computers were connected to the network from the early 1990s onwards.

The advent of the Internet and the World Wide Web have made computers much more useful than they could ever have been on their own. In developed countries, nearly every home, office, school and shop can reach out to pools of knowledge or share documents in a near-instantaneous fashion.

Developments in Understanding the Brain

In recent years, a lot more effort has also gone into understanding the manner in which the brain works, with several large-scale research endeavours being initiated. These include the already mentioned BRAIN initiative, which was launched by U.S. President Obama in 2013 to 'accelerate the development and application of new technologies that will enable researchers to produce dynamic pictures of the brain that show how individual brain cells and complex neural circuits interact at the speed of thought'.[3]

It is suggested that this, and other similar initiatives, will show how individual cells and complex neural circuits interact in both time and space, enabling new solutions to be considered to treat, cure and even prevent brain disorders. They will also provide unprecedented opportunities for exploring and understanding how the brain enables the human body to record, process, use, store and retrieve information.[4]

Another related project is the Human Brain Project supported by the European Union, which began in 2013. This represented a substantial scientific endeavour aiming at building a collaborative infrastructure allowing researchers across the globe to advance knowledge in the fields of neuroscience, computing and brain-related medicine.[5]

However, more complex philosophical questions will remain with respect to consciousness and the nature of the mind. For example, even though a better biological understanding of the brain is developing, questions remain as to whether this will ever improve the philosophical or legal understanding of what it means to be conscious or to be a moral agent.[6]

Developments in Neuronal Interfaces

Developments in neurotechnology are encouraging the brain to expand its physical control beyond the limitations of the human body. In this way, it is possible for information to be obtained from brains and for information to be provided to brains, and for feedback mechanisms to be set up in which the thoughts of a person can influence the workings of a computer or the reverse.

In this regard, one of the first to use neuronal implants was a Swiss ophthalmologist and scientist, Walter Rudolf Hess (1881–1973), who received the Nobel Prize in 1949 for mapping different areas of the brain. From the 1920s onwards, he experimented with cats, to which he implanted, while anesthetised, very fine wires into their brains. When awake, he then stimulated these wires using weak electrical current to examine their reactions.[7]

A few years later, in the early 1950s, the U.S. psychiatrist Robert Galbraith Heath (1915–99) was the first researcher to implant electrodes deep into living human brains of patients with very severe mental disorders. The patients often experienced remarkable and positive changes of moods and personalities using the stimulated electrodes.[8]

Following on from such developments, the very possibility of neuronal interfaces including devices that enable an interaction between a neuronal network and a system, such as a mechanical machine or computer, as well as a possible direct association between the mind and cyberspace, has encouraged many new ideas in futurology. This has included the prospect of 'jacking into' cyberspace or being able to upload a person's mind into a computer.

In many ways, neuronal interface systems are already in use, but many different kinds and levels of sophistication exist for such devices. Some applications, for instance, are more practical and realistic, which may assist disabled persons in recovering some of their lost functions, such as the use of their limbs. Indeed, a significant amount of work is already taking place in seeking to address motor function and sensory organs.

In the future, the use of neuronal interface systems using a computer may even improve a person's cognitive functions, such as memory, reasoning speed or access to data. But caution and realism is necessary to avoid overstating or exaggerating possible uses. Visionary proposals of bioelectronic neurocomputers and microelectronic neuroprostheses (an artificial device replacing a missing part of the brain) will not be possible in the near future, if at all, because of practical limitations.

Moreover, such interventions are not without risks, especially when invasive procedures that modify the very structure of the neuronal network are considered. Because of this, research projects using invasive systems are only considered when very serious limitations are experienced by the person. In these situations, modifications may be suggested to the brain that would otherwise be considered unethical.[9]

In the following sections, a sort of state-of-the-art presentation will be given as to what is already possible in relation to neuronal interface systems in which human neuronal networks, including the brain, can be directly associated with electronic technologies such as computers. Future prospects will then be examined, as well as the consequences that this may have on possible interfaces between the mind and cyberspace.

Procedures Involved in Neuronal Interfaces

Neuroscience has evolved over the past few decades to enable the development of new interfaces between elements in the outside world, including machines and computers, which can stimulate or record activities in the human nervous system. For instance, human brain–computer interfaces are now becoming useful tools in the development of neuroscience, bringing new insights into:

- the neuronal basis of brain function;
- neuronal coding and representation;
- brain behaviour and perception;
- the neurobiological basis of certain diseases.

In order for a useful neuronal interface to be considered for a broad range of neuroscience applications, it must be able to analyse and/or stimulate specific areas of the brain for particular time periods, while addressing concerns relating to safety, usability, reliability, patient acceptance and cost.

In this regard, a number of technologies are already being developed or considered that can be used to analyse or modify certain areas of the brain over a long period of time, such as through the use of wireless technologies. Moreover, the development of a better understanding of 'background' brain activity is allowing greater control of the information coming in and out of the brain.[10]

At the moment, neuronal interfaces have generally relied on visual feedback in which a person looks at the activity produced by the interface in order to decide how best it can be controlled and used, but new forms of sensory feedback systems may become possible in the future.

Considerable interest has also been expressed for neuronal interfaces that record and process brain activity in real time through implanted electrodes. It may then be possible for the brain to learn how to incorporate this activity into normal function. These neuronal interfaces could, for example, be applied to directly control a patient's paralysed muscles. Indeed, such interfaces are already being used to directly stimulate the muscles in the body of disabled persons, while receiving feedback from the network of neurons responsible for the sense of balance or movement in these persons' brains.[11]

Applications that may prove more ethically challenging in the future are those that involve long-term modifications to the strength of connections between the neurons that are associated with learning and behaviour. In this regard, neuronal interfaces could actually modify the brain to react in a certain manner to a certain kind of stimulus in order to enhance the learning process.

Progress in the development of neuronal interfaces could also affect higher-order areas of the brain to produce what can be characterised as cognitive replacement parts, causing significant changes in terms of how the brain operates and functions. These could be considered, for example, to address the consequences of a stroke in a patient, but could, in addition, be used to manipulate and even exploit others.[12]

The technology is also enabling new uses to be considered that not only seek to restore a function, but enable human beings to be enhanced in some way or access completely new experiences. For instance, it may in the future be possible to extend neuronal interface applications to new forms of brain manipulation aimed at cognitive enhancement or neuronal 'modification' or 'correction'.

In relation to these future possibilities, three types of neuronal interface systems are generally considered: [13]

1. Interfacing out (output) of the nervous system: this enables biological information to exit a neuronal network, such as the brain, which can then

be sent to some form of computer that interprets the signal and triggers events or actions. For example, it enables brain information to be read and used in controlling a limb.
2. Interfacing into (input) a nervous system: this inputs information into a living neuronal network from outside, such as from a computer. For example, it enables a cochlear implant to provide sound information into the brain.
3. Interfaces made of feedback loop systems: these interpret information from a living neuronal network and sends it to an external processor, which then returns information back into the neuronal network.

At this stage, it should also be emphasised that, because it is difficult to see into the future, it is impossible to predict which technologies may become relevant in the development of neuronal interfaces and the resulting association of the mind with cyberspace. Therefore, the following list of neuronal interface systems is merely a summary of what is already beginning to exist in order to present what may eventually be possible.

Output Neuronal Interface Systems: Reading the Brain and Mind

The brain is often said to be similar in consistency to cold porridge, with the skull offering a huge degree of protection in normal life; however, it also keeps the brain out of reach from any form of simple observation. Because of this, and as already discussed, it was only at the beginning of the nineteenth century that biologists, such as the Frenchman Jean-Pierre Flourens, began to understand that different functions could generally be ascribed to particular regions of the brain, though a finer localisation was a lot more difficult.

Yet, as a result of Italian physician, physicist and philosopher Luigi Galvani's (1737–98) discovery that nerves and muscles were electrically excitable, Flourens and the Italian anatomist Luigi Rolando (1773–1831) were able to begin examining how parts of the brain could be electrically stimulated. This revealed further information about what areas corresponded to which function.

The first serious mapping of the brain started in the early 1800s, with scholars such as the German neuroanatomist Franz Joseph Gall (1758–1828) publishing in 1805 his *Lehre von den Verrichtungen des Gehirns* (*Lessons on the Activities of the Brain*). In this, he correctly proposed that different parts of the brain generally had different functions, but incorrectly suggested that these functions could be studied by examining the exterior of a person's skull. The concept became known as phrenology.

In actual fact, in order to determine what is happening inside a brain, it was necessary to measure the electrical signals that are present in a neuron or group of neurons. Historical research in this area dates back to the 1950s, with the examination of squid neurons, which are exceptionally large and easy to manipulate. The final aim was to obtain a complete read-out of the state of a brain by measuring every single electrical signal in every brain neuron.[14]

At present, neuronal output interfaces that can be used to analyse brain functions are very much anticipated by scientists. The aim is for electrical signals from the brain to be interpreted in order to predict cognitive intentions, such as performing a movement, meaning that they could eventually replace any lost connections that a person's brain has with his or her body or any other machine. Nonetheless, neuronal interfaces could eventually become the preferred way for human beings to interact with computers instead of using keyboards, touchscreens, mice and voice command devices.[15]

Interfacing out of the brain with output neuronal interface systems can take place, first of all, though the means of electrodes that can either be situated on the surface of the skin of the head (noninvasive) or inside the skull (invasive). The different types of electrodes used result in significant differences in success rates in terms of making contact with the desired area or cell type in the brain. Safety concerns also vary depending on which kinds of electrodes are used or where they are located. For example, surgery is required with implanted and invasive electrodes, which is associated with a number of risks.

Another more general and indirect read-out of brain activity can be obtained through different kinds of scanning procedures. These do not directly measure the electrical activity of neurons, either individually or in groups, but rely on the fact that thinking necessitates small amounts of energy that can be measured in terms of the variation of brain metabolism. But this still has many limitations and can only be used for some of the most basic brain activities.[16]

Invasive Output Neuronal Interface Systems

The first experiments using invasive neuronal interfaces with electrodes placed inside the brain were undertaken on nonhuman primates, such as Rhesus monkeys, in the 1970s in the United States.[17] From these experiments, a relationship was discovered between the electrical responses in the brains of these monkeys and the direction in which they moved their arms.[18] More recently, experiments using electrode implants in the brains of the same species of monkeys have been undertaken to associate brain signals with their use of a mechanical robotic arm. [19]

Research on invasive output neuronal interface systems is now increasingly being considered to provide new functionality to certain disabled persons. In this regard, one of the first experiments took place in the year 2000 whereby a number of electrodes were implanted into the brain of an individual who had suffered a stroke, resulting in paralysis. This enabled the patient to learn to move a cursor on a computer screen by thinking about various hand movements.[20]

By and large, the best resolutions obtained from brain signals with humans involve the implantation, through surgery, of very small electrodes directly into the brain of an individual at a depth of about 1.5–3 mm. This enables the recording of signals from very small groups of neurons giving the greatest level of control.[21] But since functions in the brain are not usually associated with a single group of neurons, it is often necessary to consider a more general picture of the brain using a number of electrodes.[22] However, it should be noted that such invasive neuronal interfaces are prone to scar-tissue build-up, which may cause the signals to become weaker, or even non-existent, as the body reacts over time to the foreign device in the brain.

Partially Invasive Output Neuronal Interface Systems

Some neuronal interface systems are less invasive and can analyse brain signals on the surface of the brain but inside the skull. In this case, because there is no forced penetration of the brain, less damage is inflicted to the cerebral cortex.[23] But in these partially invasive systems, the electrodes are still positioned through surgery with the associated risk of infection.

Recordings through partially invasive systems may provide a better spatial resolution than those recorded on the scalp and may enable greater stability than recordings taking place inside the brain. However, their resolution usually remains inferior to more invasive neuronal interfaces and, so far, only limited investigations have been undertaken on humans.[24]

Noninvasive Output Neuronal Interface Systems

Noninvasive output neuronal interface systems usually analyse brain activity through the use of neuroimaging, including the application of electrodes on the surface of the head rather than through direct implantation inside the skull. This makes surgery unnecessary and avoids the associated risks of neuronal damage and infection. In this way, a kind of image of what is happening in the brain is examined. Clinical applications for human disorders are progressing only slowly. These include neuronal interfaces used to analyse movement intentions for patients who are paralysed.[25] They can also be considered for patients who are not able to express themselves, such as locked-in patients, who retain cognitive functions but cannot move or communicate verbally due to complete paralysis of nearly all voluntary muscles in the body.

As a result of developments in the medical field, other applications are now being considered, such as in the gaming industry. Examples of games that use noninvasive neuronal interfaces include those where participants wear headsets while trying to control, through their thinking, the motion of a small ball on a screen. The headset measures brain activity by way of multiple electrodes placed on the outside of a person's skull, while using brain sensors linked to wireless technology to control the ball.[26]

Neuroimaging

The term 'neuroimaging' refers to a group of noninvasive technologies that acquire measurements of the brain's structure, biochemistry or function without having to physically investigate the brain. They generally measure the architecture and activity of large populations of neurons and usually interpret signals from many locations throughout the entire brain simultaneously.

The procedures presented below differ in terms of their: (1) spatial resolution (how well they can distinguish between two close points in the brain); and (2) temporal resolution (how well they can distinguish between two close moments in time). Unfortunately, there is often a trade-off between these two forms of resolution, though this can often be addressed by using a combination of procedures.[27]

Neuroimaging techniques can also be classified into two broad categories, namely 'structural' (or anatomical) neuroimaging, which observes the brain's architecture, and 'functional' neuroimaging, which examines images that reflect the brain's activity.[28]

X-Rays

One way to look inside the skull of a human being is through X-ray photography. This originated with German physicist Wilhelm Roentgen's (1845–1923) discovery of high-energy particles in 1895 and his realisation that they could pass through solid objects leaving a shadow-like image on a fluorescent screen. Indeed, his observation that the beam of particles only reflected the bones of his wife's hand launched a whole industry.[29]

The images are useful in determining the shape and structure of hard materials in the human body, such as bones and kidney stones. But when the rays pass through soft materials, such as the brain, only a small effect is noticed. Thus, on their own, X-rays have little to offer the brain scientist or neurologist.

Computed Tomography (CT)

Adding computers to X-rays enabled more information to be obtained, since X-rays can come in many different power settings showing up different kinds of soft tissue. Thus, a Computed Tomography (CT) scanner can take thousands of horizontal brain images, in sections, using varying levels of X-rays that can then be used by a computer to build up these fragments of information to create a picture. With enough scans, it is even possible to create a three-dimensional image of the whole brain.

The first clinical CT scan on a patient took place in 1971 in England.[30] The patient had a suspected frontal lobe tumour and the scanner produced an image with a sufficient amount of detail to see the growth. Since then, image quality has improved and CT has become a valuable clinical tool. For example, it is used in many hospitals throughout the world to immediately assess the results of a stroke or head injury, since it has the ability to quickly detect bleeding within the skull. Moreover, CT scans can be used to look for brain tumours in a person or to better evaluate, in more detail, abnormalities seen in normal X-rays. However, it is worth noting that for research and increasingly many clinical purposes, CT has now generally been replaced by Magnetic Resonance Imaging (MRI).

Positron Emission Tomography (PET)

Positron Emission Tomography (PET) scans were developed in the 1970s and have revolutionised the understanding of how the brain works. The procedure requires a patient to lie in a scanner, while radio-labelled trace particles, such as a radioactive form of oxygen, are injected into the blood to be used as markers. The scanner then detects the radioactivity of the tracer molecules, thereby creating real-time images of the concentration of these tracers in different parts of the body.

When it is used to look at the brain, PET may reveal which areas are most active while a person performs specific tasks. For example, it is possible to ask a person to imagine doing nothing or playing tennis. The computer can then compare the two sets of images, making it possible to distinguish an increase in radioactivity in a particular area that is related to the blood flow changes resulting from brain activity. In other words, the rise in radioactivity in a certain region indicates that the brain is working harder and calling in more oxygen. While such assumptions are probably correct, a difficulty exists in that it is usually a whole area of the brain that 'lights up'. PET scans can therefore provide information about general function, but give little or nothing in the way of fine detail.

Magnetic Resonance Imaging (MRI)

It was in 1980 that, for the first time, a UK team used a Magnetic Resonance Imaging (MRI) machine to obtain a clinically useful image of a patient's internal tissues. This identified a primary tumour in the patient's chest, an abnormal liver and secondary cancer in his bones.[31]

An MRI scanner consists of a large cylinder containing an extremely powerful magnet. When a patient lies inside the scanner, a magnetic field is then created, causing changes in the magnetic properties of atoms in the body, which are subsequently analysed through a computer in order to produce images. These include pictures of organs, soft tissues, bone and virtually all other internal body structures. One of the advantages of MRI is that the different elements of a brain structure can be given different contrasts, enabling a detailed anatomical structure to be visualised.

Detailed magnetic resonance images are now the most sensitive imaging test of the head and brain in routine clinical practice. They can indicate if there are any changes in shape caused by a tumour, stroke or injury and can also be employed to investigate neurological disorders such as Alzheimer's disease and epilepsy.[32] However, MRI cannot show anything about the cell-level functioning of any of the brain areas.

Functional MRI (fMRI)

The most widely used extension of MRI to detect aspects of neuronal activity in the brain is called functional Magnetic Resonance Imaging (fMRI), which uses Blood Oxygenation Level Dependent (BOLD) imaging. This measures changes in the oxygenation level of the blood and indicates which areas of the brain are most active at any given time. These variations arise because neurons consume oxygen when they are active, which leads to compensatory changes in local blood flow to the active area.

Usually, fMRI is used while a participant performs certain tasks, enabling researchers to associate brain activity with sensory, motor or cognitive processes. But it is important to emphasise that BOLD measures neuronal activity indirectly through measuring changes in blood oxygenation levels. Since blood flow takes place several seconds after neuronal firing, this limits the temporal resolution of fMRI, meaning that although the image is detailed, it is impossible to observe rapid changes in activity.

Typically, fMRI is combined with a rapid production of brain data, giving a continuous series of images of the brain – one every few seconds over a period of about 40 minutes – while the participant performs particular tasks. This enables an examination of the nature of brain processes with respect to brain activity.[33]

It should be noted that fMRI has now largely supplanted PET for providing dynamic images of brain activation because it is an entirely noninvasive recording of neuronal activity across the entire brain with relatively high spatial resolution (range of millimetres) and moderate temporal resolution (range of seconds).[34]

However, caution should be shown when interpreting the statistical probability of results obtained from fMRI, especially in cognitive examinations, since a significant amount of fMRI research on emotion, personality and social cognition may be using unreliable procedures.[35]

Electroencephalogram (EEG) and Magnetoencephalography (MEG)

Ever since the German psychiatrist Hans Berger (1873–1941) invented the electroencephalography (EEG) in 1924 by attaching multiple electrodes to the outside scalp of a head, a form of direct communication between the brain and an external device has become possible.

A similar procedure called magnetoencephalography (MEG), in which sensors replace the electrodes on the head to record naturally occurring magnetic fields produced by electrical currents in the brain, was then developed.

In this regard, measurements are now usually collected by placing up to one hundred electrodes or sensors on the person's head using a wet gel to improve contact with the skin.[36] These are sometimes attached individually or built into a cap.

EEG detects the very small synchronised electrical activity of many hundreds of thousands of neurons, whereas MEG detects the very small changes in magnetic fields associated with the electrical activity of these large groups of neurons. These results enable the production of a 'map' of human brain activity second by second associated with thought processes directly and noninvasively.

However, the spatial resolution of EEG and MEG is limited because of the difficulty in measuring electrical or magnetic signals deep within the brain and the intrinsic complexity of trying to correspond signals on the scalp with activity in specific brain areas. But EEG can still be used, for example, to detect general patterns of electrical activity resulting from thought processes or the brain waves that occur during sleep. When a person is asleep, his or her brain goes through a number of cycles of activity. Initially he or she will be in a light sleep and the surface electrodes will record small amplitude high frequency waves. As a person moves into a deeper phase of sleep, the waves increase in amplitude and decrease in frequency. It is then possible to see specific patterns associated with dreaming.

Indeed, when individuals wake up from a deep sleep, their brainwave frequencies will increase through the different specific stages of brainwave activity. During the waking cycle, it is possible for individuals to stay in the mixed state of activity for 5–15 minutes, whereby their brain is running through a free flow of ideas about previous events or contemplating the coming day's activities. It can be an extremely productive time filled with meaningful and creative mental activity.

Another advantage of EEG is that the electrodes are readily available and portable, making it far easier to use than other methods. Moreover, since EEG and MEG provide a measure of brain activity that directly reflects the electrical activity of neurons, in contrast to the indirect signals related to blood flow measurements obtained from fMRI and PET, which have a better spatial but worse temporal resolution, they are often used in cooperation.

Though EEG does not involve as many risks as more invasive procedures, it does have some disadvantages. For instance, muscle contractions in the face or other electrical appliances may interfere with the recording of electrical signals in the brain. Some training is also required for a person to appropriately use the technology and interpret the results.[37]

Near-Infrared Spectroscopy (NIRS)

Near-infrared spectroscopy (NIRS) is a noninvasive procedure enabling the absorption of light at near-infrared wavelengths to be measured. By applying such a light source and array of detectors to the intact skull of a person, a measurement of how much light is transmitted can be examined. This is especially used with infants who have relatively thin skulls and in combination with other imaging procedures. However, NIRS has a relatively low spatial resolution because of the difficulty in seeking to localise scattered light through a skull and the limited penetration of infrared light into a brain.[38]

Other Output Systems

Other interventions exist enabling a significant amount of information to be gathered from the brain, including the exact position of all the neurons and their interactions, but these cannot be considered as interface systems since they would require the individual to have died. However, because some of them are already being suggested in the very improbable context of mind uploading (which will be considered in a later section), these will now be briefly presented.

Light Microscopy

Light microscopy has developed quite significantly in the last few decades. Automated systems can now even slice, represent and analyse entire brains from dead mice in a day, generating a considerable amount of useful information. More advanced systems are capable of creating three-dimensional models of mouse brains that take about a week to prepare.

The importance of these procedures is significant when combined with careful staining systems. In this way, it is possible to place a stain in one zone of the brain and then, after a fixed amount of time, to kill the animal in order to study in which parts the dye has diffused. Adding different types of dyes under different circumstances to different parts of the brain enables neuroscientists to build a massive three-dimensional map or catalogue of all the neuronal connections. By the time the data from thousands of mice is added (each one being killed in the process), it is possible to obtain a fascinating overview of life inside a mouse brain.[39]

Doing this for a human brain is theoretically possible, but there are some insurmountable obstacles: first, it requires a number of brains from deceased persons so that they can be cut into slices; second, it requires that appropriate dyes be added to specific parts of their brains just before these persons die; and, third, it requires massively scaled-up machines that provide a very large amount of data.

The resolution of these systems is very good, but it is only possible to determine where neurological cells begin and end, without knowing very much about the final terminals, the intercell communication systems (the synapses). This lack of knowledge significantly restricts any understanding of what is really going on at each nerve ending.

Electron Microscopy (EM)

With electron microscopy (EM), which requires the brain to be dead, frozen, sliced and stained, it is possible to observe the very small junctions between the neurons. EM generates very good images of these complex junctions, providing a detailed understanding of the structure of small volumes. However, it is not feasible to scale this up to the level of a mouse brain, let alone a human.

Input Neuronal Interface Systems: Changing the Brain and Mind

As already mentioned, scientists such as the Italian Luigi Rolando started to electrically stimulate parts of nonhuman animal brains back in the eighteenth century, while examining whether these were similar to those found in humans. This eventually resulted in clinical applications, with input neuronal interfaces providing stimulation to specific parts of the neuronal network in seeking to restore or improve function.[40] These are technologies that take signals from the outside and provide it to an individual's neuronal system. Again, they can be classified as invasive and noninvasive procedures.

Invasive Input Neuronal Interface Systems

Neuronal Implants for Deafness

A number of different technologies have been, and are continuing to be, developed over the years to address the diminished, or complete lack of, hearing function in certain individuals. These have revolutionised the options offered to person who want to regain a better (or even just some) form of hearing. These include: (1) cochlear implants that bypass the dysfunctional signal recognition system in the ear; and (2) auditory brain stem implants that completely sidestep the whole hearing system.

Cochlear Implants

Cochlear implants have revolutionised the lives of many individuals who were either born with no ability to hear or became deaf after birth. In a healthy hearing system, pressure waves in the air (defined as sound) enter the outer ear and make the tightly stretched fragile membrane, the ear drum, vibrate. A set of three very small bones in what is called the middle ear on the inner side of the eardrum pick up this vibration and mechanically amplify the signal. The last bone in the sequence makes contact with a spiral structure that resembles the outside of a snail shell. Known as the cochlear, this is filled with fluid and lined with millions of hair-like projections. The vibrating bones cause pressure waves to travel through the liquid, thereby deflecting the hairs. In turn, this deflection sets off an electrical impulse that travels along the auditory nerve to an area of the brain known as the auditory cortex.

A cochlear implant is used when hearing loss is caused by anything that prevents a signal entering the auditory nerve, but when this nerve remains intact and functional, such as when severe damage exists to the outer or middle ear, or when the hair cells in the cochlear have been lost.

The system works by clipping a set of about twenty very small pin-like electrodes around the auditory nerve so that the pins come into contact with the auditory nerve bundle and make close connections with the nerve fibres. A short cable is then connected between the electrodes and a sound microprocessor, containing microphones, which is normally positioned on the outside of the skull behind the user's ear so that it picks up sound in a similar way to a healthy human ear. In this way, the sound gathered by the microphone is turned into coded signals by the external processor (which selectively filters sound to prioritise audible speech), which is then transmitted to the implanted unit that converts them into a set of signals sent to the twenty different electrodes.

Accordingly, a cochlear implant works very differently from a conventional hearing aid. Instead of simply boosting the sound and blasting it to the eardrum, the implants generate signals that are sent straight to the auditory nerve. In this way, they bypass the physical mechanism that pick up sound in normally hearing people, while, at the same time, circumventing many of the problems that may develop in people who have difficulties in hearing. For first-time users, the response is instantaneous. Even people who have been deaf from birth have an immediate sensation that they may equate with sound, though quite what they are hearing is difficult to determine.

The auditory nerve has about 30,000 axons (all associated with their respective neurons), which would normally be linked to individual hair cells. This accounts for a human being's faculty to distinguish between very small differences in tone, as well as his or her ability to detect multiple frequencies all at once. However, with a cochlear implant, the entire bundle is stimulated by just twenty pins. Consequently, much of the detail will be lost. If the person was deaf since birth, another layer of uncertainty may exist, in that his or her auditory brain cortex will never have received a signal and will be untrained.

The first neuronal implants have been remarkable, but current research is driven by a need to find new ways of making hundreds or thousands of connections with the auditory nerve, while making sure that those connections are stable. Currently, the twenty electrodes just sit within the nerve bundle and if they move a little, then it does not make too much difference. They were never located to a specific axon. However, if the number of connections goes up, then it will be important for movement to be reduced. Given that axons are fractions of a millimetre in size, the smallest movement could cause the electrode to move relative to the axon.

Auditory Brainstem Implants

A further step in the treatment of people with severe hearing loss is to bypass not only the outer, middle and inner ear, but also the auditory nerve itself. This is at an earlier stage of development, but neuronal interface implants, consisting of an array of very small electrode needles, have already been positioned directly into the auditory area of the brainstem of patients.

The process requires surgery into the skull that is far more invasive than just placing the electrode on the cochlear nerve.

At the moment, such implants are not as good at conveying sound as when cochlear nerve implants are used, but they can help a previously totally deaf person become more aware of everyday sounds. However, it can take months for the hearing area of the brain to learn to use this new input. At first, patients describe the sound as indefinite noises, but over time users can pick up a sensation of pitch and loudness.

The device has already been implanted into several thousands of adults and, in 2013, the U.S. Food and Drug Administration approved a clinical trial for children in America.[41] A few devices have also been implanted in children in Europe.

A 2012 study of brainstem auditory implants concluded that most people who received them developed functional hearing, with awareness and recognition of environmental sounds. It also enabled some to enhance their lip-reading skills, while a number acquired enough speech recognition to conduct telephone conversations.[42] But some patients still go through the trauma of surgery while receiving very little (if any) benefit from the devices.

There is also an active debate about whether these implants should be offered to more children. On the positive side, the auditory system continues to be developed over the first decade of life. Fitting a device during that period would increase the brain's likelihood of adapting to its signals. Research demonstrates that the brain is particularly malleable before the age of two. This means that the implants may be particularly powerful if put into very young children.[43]

On the other hand, positioning the electrode is accomplished by destroying the cochlear. This means that it is a once-in-a-lifetime decision when the device is installed and rules out any other technology that could be developed in the future. This can be particularly pertinent when considering such an implant for a young child, given the pace of progress. It may well be that a far superior device may become available long before he or she reaches adulthood. In addition, it is uncertain how the implant will respond as the child develops, since there is a risk that the interface may be pulled out of place over time.

Future Developments with Neuronal Interfaces for Hearing

Using a phone is currently hard for some people with hearing implants because the sound from the phone's loudspeaker has to be picked up by the microphone and then processed. Therefore, it has been suggested that a mobile phone capability be built directly into the implant, enabling the person to be hardwired into the phone system. In order to overcome any risks of having a microwave transmitter so close to the brain, it may also be possible to send the signal using a pocket-held transmitter. In addition, wireless interfaces are being considered that would reduce the need for communication wires.

Interestingly, there would be no need to limit the input to phone calls. This sort of device could, theoretically, let a person listen to radio and watch television with the volume on mute. In addition, there is no reason why the microphone should be limited to picking up sounds in the normally audible range. Bats navigate by emitting high-frequency sounds and picking up the echoes, so it may be feasible in the future to build a similar system into implanted devices. In theory, a person could then switch to night operation and turn their hearing system into a navigational radar.

Resistance from the Deaf Community

It would be easy to assume that everyone who cannot hear will be excited by these developments and would welcome the possibility of implants. But this is not the case. Without the ability to hear, deaf people have developed various forms of sign languages and, just as with different spoken languages in different parts of the worlds, a strong culture has developed amongst deaf persons in which signing is a critical element.

Individuals are brought together by their need to sign and this gathering brings a distinct identity. People in these communities use the capital D deliberately saying they are Deaf, in the same way that others would say they are French or German. This means that an implant that removes deafness may be considered as a highly disruptive technology and could be seen by some as unwelcome. The strength of feeling is such that, on occasions, Deaf parents whose condition is the result of having particular genes have argued to be allowed to use embryo screening to choose Deaf offspring. Their desire is to have a child who can join in with their community rather than be part of a 'foreign' social identity.[44]

Retinal Vision Implants

Vision implants are also being considered to treat non-congenital (acquired) blindness. In this regard, a very limited visual sensation has been possible with retinal implants in which a digital camera is worn by the user that transmits an image, through an electrical signal, to an electrode array implanted on the back of the retina of his or her eye. This gives some general perception, but a number of limitations still remain, including biocompatibility problems.

One of the first researchers to study the possibility of using neuronal interface systems to restore sight was undertaken by the British physiologist Giles Brindley in 1968, who implanted an 80 electrode device on the visual cortical surface of a 52-year-old blind woman. As a result, she was able to recognise some directly induced patterns.[45]

Further experiments were developed by the American biomedical scientist William Dobelle (1941–2004). In 2000 he indicated that he had used cameras mounted on glasses to send signals through a computer to a 68 array of very small electrodes implanted into a blind person's visual cortex, which succeeded in producing the sensation of seeing light.[46]

Future Developments with Neuronal Interfaces for Vision

Further developments are now being considered that use more sophisticated implants, such as wireless interfaces, enabling better and more coherent vision. However, in order for good images to be obtained on the retina, a large number of very small electrodes would be necessary, enabling an important amount of information to be received without creating a lot of heat that would otherwise damage the surrounding tissue. Moreover, in a similar manner to auditory interfaces, implants that are directly linked to the visual cortex are now being examined.

Interestingly, if progress continues to develop with this technology, it may be possible for a person to distinguish the near-infrared region, which would be of great value in night driving.[47] In fact, research published in 2013 has already demonstrated how sensitivity to infrared light can be developed in rats through the use of implanted devices.[48] In addition, just as with hearing neuronal interfaces, it may be possible in the future to hardwire a person directly into the output of a video machine so that the person will 'see' pictures sent directly by a computer.

Deep Brain Stimulation (DBS)

Deep brain stimulation (DBS) was initially developed in France in the late 1980s. It involves employing long needles, which can be manufactured with multiple electrodes on either their tip and/or their length. Using image-guided surgery, these are carefully pushed deep into the brain of a person to the position where it is believed the neurons are malfunctioning. In an attempt to address this functional deficit, pulses of electric current are then sent down to the affected region, resulting in a possible dramatic and positive effect on symptoms.[49]

Interestingly, what actually happens at the end of the electrodes remains unclear, but it is likely that the creation of a small current between the electrodes excites the neurons in the surrounding area and modifies communication between them.[50] DBS has also been shown to initiate very real and important, metabolic and neurochemical brain changes when continual stimulation takes place.[51]

Applications of Deep Brain Stimulation

In the past few decades, DBS has increasingly been considered as a treatment option for certain serious disorders. It has even been shown that placing electrodes in specific brain areas reduces tremor and rigidity in patients affected by Parkinson's disease, increasing their ability to move and walk. In other situations, the procedure has been used to control chronic pain, epilepsy, migraine, depression, Alzheimer's disease and obesity, with variable reports of improvement.[52]

However, with DBS, there is always a risk of damaging blood vessels in the brain or disturbing previously healthy regions as the electrodes are inserted. This means that the procedure can only be used in patients with severe symptoms that cannot be controlled by pharmaceutical treatments.[53]

DBS electrodes can also be connected via a subcutaneous extension wire to battery-driven stimulus generators that may be implanted subcutaneously so that the system is located entirely within the patient's body.[54] But it is important to note that even though DBS is an intervention that may increase the patient's quality of life, which is otherwise restricted by his or her illness, it is neither life-saving nor curative.[55]

From a more research-based perspective, DBS offers the ability to study specific and important brain functions and cognitive abilities while considering them in real time. For instance, it is possible to examine the effects of DBS on agency and decision-making because the procedure can directly change a person's mood and behaviour by modifying the biological neuronal basis of unconscious and conscious mental states. This can be done either intentionally, if the individual was affected by a major psychiatric indication such as a serious depressive disorder, or as an unintended consequence of the procedure that was undertaken for another reason.[56] On this account, the European Parliament's 2009 Science and Technology Options Assessment's report entitled *Human Enhancement Study* indicated:

> [A] presupposition underlying much of the debates on the societal and ethical implications of technologies such as DBS is that they manifest that medicine has come to grips with something that was until recently considered to be out of reach of direct medical intervention: the mind . . . The capacity of turning on and off emotions, moods, motor control . . ., simply by switching on or off one's DBS, appears to powerfully illustrate this enlarged power of science and technology.[57]

In this regard, the fact that DBS may have a direct, unconscious effect on a patient may give rise to questions about his or her ability to make free will decisions, since it in unclear whether it is the patient or the DBS device that is actually in control of his or her different moods and their consequences. For example, if the depressive symptoms of certain patients can only be addressed by DBS, then they may be uncertain whether they are, in fact, in complete control of their behaviour and thoughts. However, control is very likely to be a matter of degrees depending on the manner in which DBS may affect different persons.[58]

It is also possible to examine the way in which patients' experience with DBS can affect their concepts of identity and how it alters their sense of who they are, whether or not they are even aware that this change has occurred. Indeed, the influence of DBS on identity is unique in that:[59]

1. DBS is an implantable system that is foreign to the brain and that can be switched on and off – in this respect, the device can be used to study changes to the sense of identity of a person;
2. there may be a difference between the identity change noted by the patient and the persons in contact with him or her – this is because the patient may still consider that he or she is the same person, while others may believe he or she has become a different person.

Therefore, serious questions are still being asked about the use of DBS in certain circumstances.[60] But this has not stopped new possible, non-clinical neuro-enhancing applications of the procedure to be considered, though further investigations relating to its efficacy and ethics would be necessary.[61]

This all means that ethical and legal questions with DBS are very real. These include questions surrounding the context of autonomy, accountability as well as liability, and whether it should be possible to use DBS for non-medical reasons.[62]

Fibre-Optic Cable Light-Sensitive Neurons

Another new, though still very much experimental, procedure enabling scientists to study brain functions uses genetically engineered neurons in rodents, which are light-sensitive. When these are then exposed to blue light delivered by a fibre-optic cable, the neurons are triggered to transmit a signal to cells downstream in the neural circuit. Thus, by making specific groups of neurons fire at will, it is possible to study specific connections in the brains of the rodents.[63] However, no applications of this technology are, as yet, being considered for human beings.

Noninvasive Input Neuronal Interface Systems

Transcranial Brain Stimulation (TBS)

Though some forms of brain stimulation such as electroconvulsive therapy (ECT), in which seizures are electrically induced in patients when seeking to provide relief from psychiatric disorders, have been used since the 1930s, these will not be discussed in the following study since they do not have any further applications in neuronal interfaces.

But one group of appliances that is increasingly being considered is Transcranial Brain Stimulation (TBS). This refers to a set of noninvasive applications that stimulate the brain either by inducing an electrical field using a magnetic coil placed against the head in transcranial magnetic stimulation (TMS) or by applying weak electrical currents via electrodes on the scalp with transcranial direct current stimulation (TDCS) and transcranial alternating current stimulation (TACS).

The principle of electromagnetic stimulation underlying TBS is that electrical currents can be created to selectively activate certain parts of the brain, producing particular outcomes by affecting large volumes of neurons. They are generally considered in research since TMS and TDCS can be used to both suppress as well as stimulate neuronal activity. They are thus particularly useful when combined with purely observational neuroimaging techniques, since the procedures can examine whether the activity of neurons in a specific brain area is necessary or causal for a certain brain function.[64] TBS can also be used to understand the functioning of the brain by tracking networks and pathways.

The ability to modify brain activity raises the question whether TBS procedures may, in addition, be able to deliberately change brain functions and, as a consequence, modify thoughts or behaviour. Interestingly, some of these procedures are already being used in clinical settings, such as in trying to address drug-resistant depression or treat other psychiatric and learning disorders, though the exact mechanisms of their therapeutic effects are still being researched.[65] But already 10,000 adults have undergone such stimulation, which seems to be safe in the short term.[66]

Transcranial Magnetic Stimulation (TMS)

Transcranial magnetic stimulation (TMS) has been used by scientists since the mid 1980s, especially in studies examining motor control. The procedure involves placing a coil of wire (enclosed in plastic) near the scalp over the brain area to be stimulated and then delivering a pulse of large current lasting less than one millisecond. This produces a magnetic field, creating weak electrical currents inside the brain through electromagnetic induction. As a result, the thousands or millions of neurons in the area below the coil are briefly stimulated, in a nonspecific fashion, to a depth of approximately 3.5 cm into the skull, thereby affecting cognition or motor function.

As such, TMS may be used as a diagnostic tool as well as in research, where it is employed, for example, to examine how the pulses alter the amount of time it takes for a person to recognise a face, add numbers or complete sentences.[67,]

In 2008, the U.S. Food and Drug Administration approved TMS to treat migraine and refractory depression in adults,[68] and there are no known long-term effects, though there is a very small risk of initiating an epileptic seizure during stimulation.[69] The procedure is also increasingly being considered to address a number of psychiatric and neurological disorders such as mania, obsessive-compulsive disorders, schizophrenia and Parkinson's disease.[70] At the same time, there is some evidence that TMS could be used for cognitive enhancement for healthy individuals, including improving cognitive skills, moods and social cognition.[71]

However, one of the challenges with TMS is that the stimulation effects are generally only temporary. Difficulties also exist with directing the magnetic pulses to a specific area in the brain that is responsible for a certain function without activating other areas as well.[72]

Transcranial Direct Current Stimulation (TDCS) and Transcranial Alternating Current Stimulation (TACS)

The noninvasive stimulation of the brain through the use of electrical currents is not new. Ever since the beginning of the twentieth century, it has been possible to apply electrodes to the scalp of a person, enabling an electric current to be created in the brain.[73]

With TDCS, a weak electric field is applied to the scalp (using noninvasive electrodes) in the region of interest, thereby inducing intracerebral current flow leading to alteration of brain function. In a research setting, measurements can then be obtained through the study of small reaction time changes in behavioural performance on psychological tasks.[74]

Recent studies in stroke rehabilitation strategies have shown that TDCS may improve a patient's ability to learn a simple coordination exercise, with improvement remaining three months after the end of the experiment. Studies are also taking place with the aim of treating depression and the effects of Parkinson's disease.[75]

In addition, it has been suggested that the procedure could be used to enhance the cognitive ability of healthy people by improving working memory, word association and complex problem-solving.[76] For example, in 2016, the U.S. military reported that TDCS could improve skill learning and performances, such as multitasking of air crew and other military personnel.[77] Other studies have suggested that several sessions of TDCS applied to the prefrontal cortex improved the moods of some individuals for several weeks[78] or made people less likely to take risks.[79]

In this regard, although devices prescribed for medical treatments must meet specific safety standards, there is currently no legislation in Europe or the United States regulating the use of TDCS for persons who simply hope to enhance certain aspects of their cognition. TDCS headsets can even be purchased online, enabling them to be used (even on children) without taking into account the eventual risks.[80]

With TACS, the procedure is similar to TDCS, but alternating current is used instead of a direct current. This causes the underlying neurons of the brain to oscillate at specific frequencies.

Feedback Systems of the Brain and Mind

In the previous sections, output interfaces were considered that involved communication technologies that externalise information from the brain. Input interfaces were then examined, enabling signals taken from the outside to be internalised into the brain of an individual. These are characterised as unidirectional devices.

But these two technologies can now be brought together, forming interactive feedback neuronal interface systems. These would record, for instance, the neuronal activity of a person, which would then be translated to an application that can be examined by the individual for communication and control. The person could, in other words, use the feedback to modulate neuronal activity on an ongoing basis, so that the accuracy of the intended outcome can be improved, forming, as a result, a closed loop system.[81]

In a way, such a feedback system enables the neuronal interface to be used as a kind of virtual mirror of the actual neuronal activity.[82]

Closed loop systems usually include the following stages:[83]

1. externalising brain activity (output);
2. pre-processing and making sure that background noises are addressed;
3. feature extraction that correlates brain signals to a small number of variables defined as features;
4. classification of the signals corresponding to a type of brain activity pattern;
5. translation into a command;
6. feedback in which a user is then informed of the brain activity that has been recognised.

Recording of the neuronal output activity can, of course, be achieved in a normal manner through, for example, speaking or gestures that externalise signals from the brain. But it may also take place with an output neuronal interface system that records neuronal activity and sends this information to some form of computer that makes sense of the signal and triggers events or actions.

Examination of these events or actions by the individual, enabling possible feedback, can then take place through sight (for example, watching where the external device is moving) or hearing, but also through an input neuronal interface that sends signals via a computer into the neuronal network.

In the future, it may also be possible for two or more neuronal interface systems implanted in the brain (for output and input or one that does both) to provide a direct neuronal feedback loop.

Brain Electrode-Chips

One neuronal interface system that may enable a feedback loop in a single device is a square microchip containing a number of very small hair-thin electrodes that can both read the state of certain neurons and also stimulate them (i.e. they are bidirectional devices).[84] These electrode-microchips can be implanted on the surface of the brain of an individual, through surgery, enabling the electrical activity from hundreds of neurons to be recorded from the relevant brain areas. This activity can then be translated into meaningful signals and sent to an appliance.

Such brain interfaces have already been considered in clinical trials with the aim of restoring some functionality for a limited group of severely motor-impaired individuals[85] whose thought signals are read in order to translate them into an application.

The pins of the electrode may look very slim to the human eye, but relative to the scale of neurons in the brain, they are massive. Consequently, each electrode can monitor the average activity of many hundreds of neurons, which is far beyond the more intricate level of activity in which the brain operates.

Electrodes in Capillaries

One major restriction of electrode-chips is that they only monitor the effect of large groups of neurons. This has led to a group of researchers in the United States to propose an alternative approach using the brain's extremely comprehensive network of blood vessels with capillaries that supply oxygen and nutrients to the brain's neurons. Because this reaches throughout the tissue and comes into close contact with most neurones, the scientists believe that it may be possible to feed probes through these capillaries to reach the most difficult-to-access parts of the brain with minimal disturbance.

In laboratory experiments *in vitro*, this proposal was examined using very small platinum electrodes that were successfully inserted into capillaries, which supplies oxygen through the blood, to neurons in the spinal cord. [86] Researchers now hope to further miniaturise the probe to make it steerable by employing electrically stimulated shape changes so that these very small wire-probes can be placed into the desired blood vessels and create the first true steerable nano-endoscope.

It would be an enormous technical feat if such electrodes in capillaries proved to be successful. But it is difficult to determine how they can move beyond the research stage in the near future. Indeed, in order to make connections with all the neurons in the brain, it would be necessary for billions of these very small microscopic wires to go through the estimated 25 km of capillaries that exists in a standard human brain.

Neuron-Silicon Transistors

Another approach to neuronal interface systems actually inserts an electrode into the neurone. In such a highly miniaturised and integrated device, a direct interface between neurons and silicon microelectronic systems would be developed,[87] enabling an application that could read out the electrical activity of a neuron (or even activate it in some way).[88]

It would then enable researchers to gather more information about how individual neurons work, while creating a simple memory device. However, at present, extending this system outside the laboratory would be extremely challenging.[89]

Miniature Synthetic Mesh (Neural Lace)

In 2015, scientists in China and the United States indicated that they had injected rolled-up miniature synthetic macroporous mesh (neural lace) electronics using a water-based solution in a 0.1 mm-diameter syringe into the brains of mice. This mesh, it was suggested, could then unfurl inside the mouse brain up to 30 times its size and become embedded with the living neurons.

Such a technology could enable new human neuronal interfaces to be developed, with the activities of neurons being continually monitored and manipulated through the use of microscopic sensors wired into the mesh.[90]

Interestingly, the concept of neural lace being implanted into the brains of individuals, such as young people, which then grows with them was first suggested by the Scottish author Iain M. Banks (1954–2013) in his series of science-fiction books called *The Culture*, which depicts an interstellar utopian society. In these books, the neural lace enables individuals to communicate wirelessly, including with databases, and to store their full sentience after death so that they can be re-activated. In addition, it enables all the thoughts of a person to be read, though in *The Culture*, this usually only takes place with his or her consent.[91]

Application of Feedback Neuronal Interfaces

To help pick through the complex manner in which neuronal interface systems may be used, this section will begin by considering what is already possible with respect to feedback interfaces, but will then examine future possibilities including what has crept into science-fiction films or books.

Therapeutic Applications of Feedback Neuronal Interfaces

As already indicated, by studying the relationship between brain signals, thoughts and intentions to undertake an action, brain imaging procedures may be used to externalise brain activity in a noninvasive manner. This may be useful when a person is unable to express his or her thoughts or intentions through normal channels such as speech or through certain gestures.

Neuroimaging analyses brain structures and activity in areas of the brain associated with large groups of neurons, enabling a limited kind of 'brain reading' where only a small number of thoughts or actions are considered. These have also led to an explosion of neurological investigations relating to cognitive processes in the human brain.[92]

The general aim of this research is to understand how mental processes take place in the brain and how these give rise to observable behaviour in terms of speech, thoughts, perception and motor actions or other behaviours. This can then be used to study certain brain dysfunctions associated with neurological or psychiatric disease.[93] Moreover, with MRI and PET, it is possible to localise nervous activity to within a few cubic millimetres, which is useful in terms of identifying which parts of the brain are involved in which kinds of mental activity.

Assistive Technologies

The most frequently used definition of assisted technologies was given by the U.S. Technology-Related Assistance of Individuals with Disability Act of 1988 as 'any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase maintain, or improve functional capabilities of individuals with disability'.[94]

In this regard, one of the first instances where neuronal feedback interfaces were considered was with patients who have a normally functioning brain, but experience dysfunction or paralysis in a certain part of their bodies. These included persons who still have a capacity for planning and imagining movement, [95] such as those suffering from spinal cord injury, stroke or amputation.[96] Accordingly, these new interfaces were developed with the aim of obtaining data from their neuronal networks and transmitting this to an appliance in order to try and restore movement or provide help with daily living.[97]

Back in 2003, the media reported the case of a former lawyer, Hans-Peter Salzmann, who had Lou Gehrig's disease, which gradually destroyed all voluntary movement.[98] His symptoms had developed to the point where his mind was described as being locked inside a paralysed body that needed a respirator to enable breathing. But he had been taught to type on his computer by controlling aspects of overall brain activity, which were picked up by two electrodes placed on the side of his scalp that were linked to a basic computer. Typing was not fast, but it gave his mind a means of escape.[99]

The first electrode-brain chips were also developed with the aim of helping people with paralysed limbs regain some function. For instance, researchers in the United States installed a brain implant in a patient named Johnny Ray (1944–2002), who suffered from 'locked-in syndrome' after suffering a brain-stem stroke in 1997. An implant was installed in 1998 and Ray lived long enough to start working with the implant. In 2000, the researchers published a study showing how he could move a cursor on a computer screen by thinking about various movements (initially movements of his hand),[100] before going on to move the cursor simply by thinking about doing so. This permitted him to carry out tasks using the computer, including writing.[101]

However, despite further work, it is still not clear how much brain chips can help 'locked-in' patients.[102] Yet there is hope that they could eventually offer novel means of communication, independent locomotion and increased control in order to improve the quality of life of these patients.[103]

Another patient, who was one of the first to use an implanted neuronal interface, was Matt Nagle (1980–2007), who had become tetraplegic after a fight in which a knife wounded his spine. In 2004, he volunteered to receive an invasive implant and became a clinical pioneer in seeking to address the very challenging difficulties of such interfaces.[104] Implanted into the area of his motor cortex that controlled arm movement, the 96-pin electrode allowed him to become the first tetraplegic person to control a robotic arm by thinking about moving his hand. Moreover, he was able to control a computer cursor, turn on lights and operate his television.[105] Since this trial, electrodes have been tested on other paralysed individuals, allowing them to control the movement of a cursor by simply imagining this motion.[106]

Further research is also taking place in private companies, such as with BrainGate™, which aims to create interface systems to help severely disabled individuals, including those with traumatic spinal cord injury and loss of limbs, to communicate and control common functions through thought processes.[107] Moreover, as progress with neuronal interface systems improves, many more applications will certainly become available with better software, generating more appropriate movements of external devices.

What is surprising in this research is that even though many years may have passed after an injury provoked paralysis, normal brain activity for movement remains present in the relevant parts of the brain that can be modulated. The same group of neurons that normally move a limb seem to remain in a person who has become paralysed and these can be used to activate an artificial device.[108]

In addition, experiments that took place in the 1960s and early 1970s in nonhuman primates demonstrated that the activity of neurons within a specific area of the brain could be directly correlated to specific aspects of movement. This was then used to enable these primates to learn feedback control of neuronal activity without actually having to move their bodies.

Interesting, basic brain patterns seem to be similar whether movement is imagined or performed, which is a useful feature in seeking to harness brain activity to operate artificial devices.[109] Moreover, since the human brain of a person can process images even before he or she may be aware of them, this could be very valuable in providing significant advantages over other systems of control in terms of speed and accuracy.[110]

The potential practical applications of feedback systems are already assisting, repairing or enhancing motor functions in many paralysed patients. Moreover, since many who have suffered some injury, such as a stroke or an amputation, retain some brain functions to generate movement intentions, these can be used to control the new limb or device or even any muscles that are still functioning. This is possible because the patient gets an idea of how well he or she is doing through the feedback mechanism. In some advanced systems, both the computer and the person 'learn' how to work together in a sort of symbiotic process.[111] For example, it may be possible for a neuronal interface to analyse certain brain signals that are associated with movement (which are generally consciously invoked, but may also be passively produced) and translate them into information that can be used to control a device in real time in a manner that reflects the intention of the person.[112]

Such feedback mechanisms enable researchers to also explore the process of learning in the human brain in the context of short-term and long-term improvements. In this regard, a very positive achievement would be for a patient with severe paralysis to regain control, communication and independence.[113]

In 2016, it was announced that three volunteers in Italy with very sever spinal injuries were able to take control of a robot in Japan through the use of EEG and a head-mounted display that showed what the robot was seeing. In order to move the robot in real time, the volunteers concentrated on special parts of the display. Moreover, to increase the feeling of control over (and embodiment in) the robot, they were provided with auditory feedback.[114]

These experiments were undertaken in the context of the European Union-supported Virtual Embodiment and Robotic Re-Embodiment Project. This aims to break down the boundary between the human and a surrogate body existing either in immersive virtual reality or in 'real' physical reality, such as with a robot body. An illusion is then created in individuals that their surrogate body is in fact their own and acting accordingly.[115] In this regard, Andy Clark explains that:

> Our sense of bodily presence is always constructed on the basis of the brain's ongoing registration of correlations. If the correlations are reliable, persistent, and supported by a robust, reliable causal chain, then the body image that is constructed on that basis is well grounded. It is well grounded regardless of whether the intervening circuitry is wholly biological or includes nonbiological components.[116]

This means, for instance, that if a person can feel and directly control an object with his or her hand, which he or she considers to be part of his or her body, then feeling and directly controlling the same object through an advanced telemanipulator may encourage this individual to similarly consider the device as being part of his or her body. This would be true even if the telemanipulator was activated at a considerable distance from the person. However, what this would then mean for the 'sense of presence' of the individual still needs to be evaluated.[117]

Similarly, the British Philosopher Jonathan Glover indicates that:

> "[I]f signals could be sent from my nervous system to receptors in physical objects detached from my body, so that I could move those objects in the same direct way I can move my arms, it might be less clear that I stop where my body ends. These doubts would be even stronger if sensory signals could be sent back, enabling me to "feel" things happening in the detached objects. We might then say that I extend beyond my body, or else we might treat these objects as free-floating parts of my body."[118]

There is also interest in using neuroimaging, such as EEG, to detect awareness in patients who are totally 'locked-in'. To do this, patients are invited to imagine moving parts of their bodies, enabling brain signals to be recorded, indicating that they are self-aware.[119] For example, it has been shown through neuroimaging that patients who were previously thought to be in a permanent vegetative state could demonstrate a sufficient level of brain function to express certain wishes. This resulted in serious discussions on whether treatment protocols for such patients should be revised to take account of their own decisions.[120] In this regard, real-time recordings would also be particularly important for engaging patients with impaired consciousness in certain activities.[121]

However, therapeutic uses of neuronal interfaces are still usually confined to clinical research in which noninvasive techniques are the most common.[122] Yet the considerable success of these trials has generated a lot of media and public interest.[123]

Neurorehabilitation

The use of neuronal interface systems is also being considered to help persons regain or relearn motor functions when these have been limited by disease or injury.[124] Such interfaces, which are usually associated with a computer, use the individual's own muscles or body part, instead of a machine, to initiate an action.

Spinal Neuronal Interface Systems

A driving impetus behind much of the work of researchers in feedback systems is the desire to find new ways of restoring movement to people whose spinal cord has been injured through an incident like a car crash or a sporting injury. In this tragic situation, a person has perfectly healthy leg muscles, with nerves running right up to and connecting with the spinal cord, but no signal reaching them. Consequently, the muscles waste away, not because they are damaged, but because they are not used.

In theory, it seems a straightforward task to build a feedback neuronal interface system that could bridge the injury and get the person walking again. First, the system would need to pick up the nerve traffic with electrodes inserted into the working end of the spinal cord. A computer would then filter the signal and detect the traffic triggered by a person's mental commands to the leg muscles. These signals would finally be fed to the nerves that remain connected to the muscles to operate the leg and foot.

The subject would also be able to use feedback, such as watching the legs move and assessing whether they are balanced, to modulate neuronal activity on an ongoing basis. As a result, the movement that the subject is aiming for can be adjusted, promoting learning and increasing accuracy.

Such a system was considered in the United Kingdom in 1994, when a team of scientists implanted electrodes into the spine of Julie Hill, a woman who had been injured in a car crash.[125] They were then able to collect her brain signals and feed them to her muscles through computer-driven technology. After hours of exhausting testing and training, she was able to stand moderately stable, but could not begin walking.

In order to eliminate the problem of balance, the team moved Hill to a sitting down tricycle. By 1997, she was able to train herself and the system to enable her legs to push the pedals in order to power the bike. In many ways, this early attempt of what is sometimes called 'functional electrical stimulation' was a success. But Hill's equipment proved too cumbersome to use and she has now become accustomed to life as a non-walking person.

This experiment demonstrated that inserting electrodes and picking up spinal traffic through filtering the nerve impulses, so that individual nerves could be heard, was a real challenge. Furthermore, even actions as simple as standing require the coordination of many muscles from those controlling the person's toes to those regulating movement in the legs. This means that taking a computer-controlled approach to making a person walk will require tens if not hundreds of connections.

However, in 2016, Swiss scientists indicated that they had been able to treat Rhesus monkeys with spinal cord injuries using a wireless neuroprosthetic interface. This acted as a new bridge between their brains and their spines so that they could regain some control over their legs.[126]

More generally, though, researchers have experienced greater success in functional electrical stimulation when electrodes were strapped to an individual's skin directly over key muscles and a current was passed through the electrodes, making these muscles contract. With correct placement of the electrodes and an appropriate pattern of stimulation, it is suggested that individuals with spinal damage may begin to walk in the future.[127]

Synthetic Cerebellums

In 2011, scientists in Israel indicated that they were able to create a synthetic cerebellum that helps coordinate movements and was able to restore lost brain function in a rat. To do this, the researchers used a chip sitting outside the skull, which was wired into the brain using electrodes. A computer then interpreted input signals and sent a response to a different part of the brainstem (which channels neuronal information from the rest of the body) that initiated motor neurons to implement a certain movement.[128]

In order to check the device, the scientists anaesthetised a rat and disabled its cerebellum before connecting their synthetic version. They then sought to teach the animal a conditioned motor reflex – a blink – by associating a certain noise with a puff of air on the eye, until the animal blinked on hearing the noise by itself. The scientists then tried this without the chip connected and found that the rat was unable to learn the motor reflex. However, once the artificial cerebellum was reconnected, the rat behaved normally and learnt to connect the noise with the need to blink.[129]

This was a proof of concept that computer implants may one day replace areas of the brain damaged by stroke or other conditions. They could then be considered as a kind of cognitive prostheses, with the aim of restoring cognitive function to persons with brain disorders due to injury or disease.[130] Since the hippocampus plays a key role in the recording of memories, they may also assist persons who have suffered brain impairment, such as with Alzheimer's disease, to recover some function.

However, the implant may also be used to enhance healthy brain functions if a person believes that this may be necessary for some reason. [131] In this regard, in 2011, the bioengineer Francisco Sepulveda in the United Kingdom indicated that 'my bet is that specific, well-organised brain parts such as the hippocampus or the visual cortex will have synthetic correlates before the end of the century'.[132]

Non-therapeutic Applications of Feedback Neuronal Interfaces

Nerve Recording Implants

The number of individuals who have made permanent physical connections between their bodies and cybertechnology is relatively small. But one frequently cited example is Kevin Warwick, who in 2002 explored the experience of having a set of electrodes attached to one of the nerves in his arm, which was connected to machines either directly or via the web.[133] The electrode assembly measured 4 mm by 4 mm, but contained a hundred needle electrodes that were just 1.5 mm long. Leading out of the electrode was a long flexible cable connected to externally worn electronics.

Warwick and his team monitored the nerve signals being picked up by the electrodes and sent these through a computer to a robotic hand. Over a number of days, Warwick learned how to move his hand in such a way that the signals, picked up by the computer, could make a robotic hand open and close. In addition, it was able to send back information about how much pressure its 'fingers' were exerting, but Warwick could best drive the system when watching it in action. He also linked the equipment to a wheelchair and was able to start, stop and move in a desired direction.

In another experiment, he travelled to New York, where he linked his implanted device to a web-linked computer and used the signals to drive a robotic hand attached to a computer in the United Kingdom. To an extent, it showed no more than had been achieved in the lab, except that the interface between the two devices was thousands of miles longer.[134] However, this did provide a 'media moment' when members of society could begin to reflect upon the possible outcomes that could be developed through linking out bodies to cyber-aided technology. There is something distinctly intriguing about seeing a piece of machinery move in one continent when the trigger comes from an individual's nervous system on another continent.

The Use of Neuronal Interfaces in Gaming

Most of the gaming neuronal interfaces being developed involve EEG, which records brain activity using electrodes that rest on the scalp or forehead.[135] This activity is then analysed and translated into information that is used to control or bring about effects in computer-operated games.

EEG is often considered for games because it has high temporal resolution and is noninvasive, while being relatively easy and cheap to use. Interestingly, some serious gaming enthusiasts have suggested that in the future, they might be prepared to use other output brain interfaces, such as more invasive and risky implanted electrodes, to enhance their gaming experience.[136]

Currently available commercial brain–computer interface gaming applications use brain signals in the following ways:

– Passive: the output neuronal interface analyses brain signals and interprets this information to bring about a change in the game's environment without the user being in control.[137] The brain signals may also be used to monitor the player's gaming experience so that the game can adjust the level of difficulty.[138]
– Active: players control what happens in the game, through a feedback system, by either (1) imagining movement whereby the neuronal interface analyses part of the brain associated with movement, or (2) changing their overall state by, for example, shifting from feeling frustrated to calm. Some researchers in the Netherlands even created a game in which changes in a player's overall state could transform his or her avatar (an icon or figure representing a particular person in cyberspace) on a screen from a bear to an elf.[139]
– Reactive: the neuronal interface makes use of brain signals from the player associated with event-related reactions by this same player.[140] For example, this can happen when the neuronal interface uses signals from the player when he or she recognises significant information.

However, a number of challenges remain in the development of neuronal interfaces before they can be considered as a standard form of interaction in games. These include the design and characteristics of EEG headsets and how the brain signals are used.[141]

Neuronal Interfaces for Pleasure

In the 1950s, a U.S. physician, Robert Galbraith Heath, was examining how he could address psychological disorders with far less destructive neurosurgery. He did this by drilling very small holes in the skulls of his patients and inserting thin metal probes directly into the brain through which pulses of electricity were administered.

In doing this, Heath discovered that by activating certain parts of the brain, he could stimulate a rush of pleasure that restrained violent behaviours in some of his patients. Moreover, when they were given control of their own pleasure switch, it was even possible for patients to manage the variation in their moods.[142]

Similarly, in 2001, it was reported that another U.S. physician, Stuart Meloy, had patented an implant that initiates an orgasm in individuals at the touch of a button. In this regard, Meloy explained that the Orgasmatron uses implanted electrodes in the spine of an individual to create electrical pulses which initiate waves of pleasure signals whenever the person decides.[143]

Brain Decoding: Reading Minds

Neurological science has not yet reached the stage when the mental state of a person can be read, especially when the person being examined may want to conceal his or her thoughts. But research is now taking place in which computers are beginning to decode a person's thought patterns. Nevertheless, these are very crude experiments with only some elements, such as the images viewed by participants, being recognised by researchers. Such programmes need quite a lot of 'training' to recognise brain activity initiated by a range of images or film clips. In addition, a number of research teams around the world are similarly trying to analyse brain scans in order to determine what people are hearing and feeling, as well as what they remember or even the topic of their dreams.[144]

Such brain decoding began when neuroscientists realised that they could use a lot more of the information they were obtaining from brain scans using fMRI. To do this, scientists divided the three-dimensional brain into voxels (the equivalent of pixels with images) and examined which voxels responded, and in what manner, to a certain stimulus, such as looking at a face.[145] As a result, studies indicate that the responses do not just take place in one specific area of the brain, but in a much more distributive manner. Once the computer has 'learnt' to recognise these brain responses, it can then be used to predict which pictures are associated with which brain responses.

In some of the first studies, researchers were able to identify categories of objects when examining the brain scans of participants looking at objects such as scissors, bottles and shoes.[146] It was then possible, in 2008, to develop a decoder that could identify which of 120 pictures a subject was viewing.[147]

In 2013, other researchers published an attempt at dream decoding. This enabled them to predict, with 60 per cent accuracy, what categories of objects, such as cars, text, men or women, featured in the dreams of the persons taking part in the experiment who were woken up periodically and asked if they could remember what they had dreamt about.[148]

Yet many challenges remain. For example, it is difficult to associate the specific patterns experienced by an individual with the general results obtained from a whole group of persons.[149] But such problems have not discouraged certain companies from trying to use technology, such as neuroimaging, to develop lie detector tests. These would be used to check the truth of a certain statement, the reliability of memories or even any bias in a judge or members of a jury.

Such 'brain reading', if it proved successful, would create a number of significant ethical challenges with respect to privacy and whether a person's thoughts should remain confidential. The media have even speculated that such technology could, one day, bring about some form of telepathy through the continuous use of brain scans.

In this respect, some ethicists do not see any difficulties, in principle, with the development of decoding technologies as long as they are used in the right way. As such, they suggest that brain data should not be considered any differently from other forms of evidence in a court.[150]

Commercially Available Feedback Neuronal Interfaces

A range of commercially available games and other applications that employ feedback neuronal interfaces using EEG are already in existence. These range from simple games with the aim of building monuments from a number of blocks[151] to more complex three-dimensional games, such as making a ball hover in a vertical tube.[152]

In this regard, the least physically intrusive forms of technology are those that can be worn and taken off at will. In other words, they have no permanent connection, require no modification of the user's body and are simply worn like a piece of clothing. Moreover, the non-intrusive nature of these items means that they can easily be tested on people with disabilities.

The EMOTIV Interface

Founded in 2011, EMOTIV is a company that claims its researchers span over 100 countries. Its website indicates that it 'is a bioinformatics company advancing understanding of the human brain using electroencephalography (EEG). Our mission is to empower individuals to understand their own brain and accelerate brain research globally'.[153] Their products are a series of headsets with up to fourteen electrode pads that rest firmly against specific locations on the user's scalp. A connection links the headset to a computer.

There are two ways of using the devices. The first is a passive use in which the player puts on the headset, which then records patterns of activity. In gaming environments, the headset can then respond to the general level of attention, excitement or alertness. If the person is considered to have become bored, it may introduce a new character or challenge. As such, the game can tailor its level of play to each gamer's needs and experience.

Alternatively, users can learn to control their brain activity by, for example, deciding to think of a colour or a game of tennis. With practice, each of these mental activities can produce detectable patterns. Individuals with severe disabilities have found this use very helpful as a means of sending signals to a computer to initiate certain tasks.

Neuronal Interfaces for Portable Appliances

In the world of entertainment, a company called Neurosky has created a product called XWave™, which lets a user read his or her mind via a headset clamped to his or her head and connected to the phone's audio jack. The plastic headband has a sensor that presses against the user's forehead and communicates with a free XWave mobile phone application, which images the user's brain waves graphically on the phone screen. Some of the features being developed on the appliance can then be used to train both the user and the appliance to control certain functions such as choice of music based on the mood of the person.

In addition, if the user focuses his or her mind on a certain task, the graphics on the phone can be changed. For example, the overall level of brain activity can be altered so that, through the software, the person can play games that involve levitating a ball or changing a colour. These games may also become more functional if used by people with physical disabilities who may be able to control screen keyboards and mice.

Immersive Technologies

Ever since electronic games were introduced into public settings, such as bars, around the world, individuals have become used to the idea of interacting with a virtual world. This has seen the virtual nature of that cyberworld become ever more detailed and life-like, with the player being drawn ever more convincingly into the game. In this respect, three key senses are generally involved: sight, sound and touch.

As such, one of the most famous web environments enabling individuals to live virtual lives is Second Life, which is a virtual social network platform allowing its residents to create alternate personalities and avatars, drawing from real and idealised lives.[154]

However, in order to immerse the player even further, it is also possible to step into a CAVE – a Computer Assisted Virtual Environment – which is a cubic room with the walls, floor and possibly the ceiling made up of high-resolution screens. By wearing 3D glasses, the screens become windows into a virtual world surrounding the person on all sides. Using cameras that follow the user's movements, it is then possible for him or her to interact with this new world, such as a new city that a person intends to eventually visit in reality. But it could also be the inner structures of a heart, enabling medical students to acquire unique insights into its workings or enabling a researcher to consider new medical procedures.

A portable version of this sort of product has been developed through the use of head-mounted devices by companies such as Oculus and its Oculus Rift[155] headset. This is a head-worn screen with motion sensors that allow the image to shift as the wearer moves his or her head. The user may also sit at home and obtain the same basic visual experience as being in a big-screen cinema or join with other players to compete in a multiple online game.

Whole body suits extend the experience even further. As well as a 3D head-mounted screen, users can wear motion sensors positioned at all major joints. When they then move through empty warehouse-sized buildings, cameras track their every position and the virtual world image in the headset is changed by the computer using the information from their own sensors and any sensors worn by other players. Already used by some security forces, the technology allows commandos to practise different situations, such as a simulated rescue, which increases their training experiences.

How much of this technology may eventually be bypassed in the future by replacing the information coming from the different senses, such as the visual or auditory senses, with equivalent artificial information which can be sent directly into the brain is an open question. But some neuronal interfaces may far exceed what is presently imaginable.

Sensory Suites

Sensory suites in which a person pulls on a whole or a part of clothing, making it possible to experience certain physical feelings, are also being envisaged. An interface with computers would then exist, which would enable the user to wear the suits and be completely immersed in a computer-generated cyber-environment.

As such, the individual may find it increasingly difficult to know whether he or she is in real or virtual reality. The previously mentioned 'brain in a glass vat' thought experiment, in which the same information from a computer is given to a brain in a vat as is given to a brain in a normal human head, making it impossible for the brain in the vat to know where it is, would then increasingly become relevant.

Neuronal Interfaces and Telepathy

In addition, it has been suggested that a form of telepathy could, one day, be developed through wearable mobile phones that would pick up and send brain signals to users seeking to communicate.[156]

According to researchers at the U.S. company Intel, individuals in the future may no longer need a mouse or a keyboard to control their computers, televisions and mobile phones, since these will be replaced by brain signals.[157] The American Andrew Chien, vice president of research and director of future technologies research at Intel research laboratories, even indicated in 2009: 'If you told people 20 years ago that they would be carrying computers all the time, they would have said, "I don't want that. I don't need that." Now you can't get them to stop [carrying devices]. There are a lot of things that have to be done first but I think [implanting chips into human brains] is well within the scope of possibility.'[158]

But of course, it is always difficult to predict how a market would develop.

Interfaces Used in the Military

Throughout history, military conflicts have been a major driver of technological developments, especially when these are financed by large defence budgets. One example of this is the already mentioned BrainGate™, which received large sums of money from the U.S. Defence Advanced Research Projects Agency (DARPA). This was to conduct research aimed at increasing the speed, sensitivity and accuracy with which a human combatant might analyse information and respond to threats.[159]

In 2010, DARPA also awarded a $2.4 million contract to the company called *Neuromatters* to develop a prototype brain computer interface 'image triage' system as part of its *Cognitive Technology Threat Warning System* research programme.[160] The aim was to determine whether noninvasive brain computer interfaces could enhance the ability of military personnel to analyse intelligence data. This included monitoring brain activity when soldiers looked at images in order to detect any patterns that may be associated with recognising a threat.[161] The results could then be processed in real time to select images that merit further review in order to accelerate decision-making.[162] Similarly, DARPA has funded research on Transcranial Direct Current Stimulation to see if it could be helpful to sharpen soldiers' minds on the battlefield.[163]

However, this U.S. Defence Agency has not stopped there, since it has supported research examining whether neuronal interfaces may be used to control remote weaponry directly from the operators' brain signals.[164] This has resulted in a U.S. patent being filed for 'apparatus for acquiring and transmitting neural signals' for purposes including, but not limited to, weapons or weapon systems, robots or robot systems.[165] In this way, the ability to control a machine through the human brain could even make it possible for a soldier to remotely operate robots or unmanned vehicles in hostile territory.[166]

DARPA has also been interested in finding treatments for injured soldiers, though some could have spinoffs for defence applications and thereby come under the definition of 'dual use' (used for both peaceful and military aims).[167] Indeed, DARPA released a number of calls for grant applications in 2013, including the following:

– Hand Proprioception and Touch Interfaces (HAPTIX) aiming 'to create fully implantable, modular and reconfigurable neural-interface microsystems that communicate wirelessly with external modules, such as a prosthesis interface link, to deliver naturalistic sensations to amputees'.[168]

- Neural Engineering System Design (NESD) aiming 'to develop an implantable neural interface able to provide unprecedented signal resolution and data-transfer bandwidth between the brain and the digital world'.[169]
- Neuro Function, Activity, Structure and Technology (Neuro-FAST) aiming 'to enable unprecedented visualization and decoding of brain activity to better characterize and mitigate threats to the human brain, as well as facilitate development of brain-in-the loop systems to accelerate and improve functional behaviors'.[170]
- Restoring Active Memory (RAM) aiming 'to develop and test a wireless, fully implantable neural-interface medical device for human clinical use. The device would facilitate the formation of new memories and retrieval of existing ones in individuals who have lost these capacities as a result of traumatic brain injury or neurological disease'.[171]
- Reliable Neural-Interface Technology (RE-NET) aiming 'to develop the technologies needed to reliably extract information from the nervous system, and to do so at a scale and rate necessary to control complex machines, such as high-performance prosthetic limbs'.[172]
- Revolutionizing Prosthetics aiming 'to continue increasing functionality of DARPA-developed arm systems to benefit Service members and others who have lost upper limbs'.[173]
- Systems-Based Neurotechnology for Emerging Therapies (SUBNETS) aiming 'to create implanted, closed-loop diagnostic and therapeutic systems for treating neuropsychological illnesses'.[174] SUBNET could, for example, include deep brain stimulators in order to address neurological disorders such as post-traumatic stress, major depression and chronic pain.[175]

In addition, DARPA has been developing a research programme entitled 'Silent Talk', which could facilitate brain-to-brain communication. Interestingly, the possibility of an immediate exchange of thoughts between a number of human beings, using for example a WiFi system, may serve to blur the distinction between an individual's particular sense of self and that of a collective of persons all linked into the same system.[176]

In this regard, the Dublin-based ethicists Fiachra O'Brolchain and Bert Gordijn indicate that: 'Determining the individual consciousness in such a situation may become increasingly difficult.'[177]

Synthetic Biological Brains

Scientists are also considering the possibility of developing synthetic brain organoids which are very small human brains grown entirely in the laboratory. In this regard, ethical challenges would arise if they eventually became conscious in some way. Because of this, Julian Savulescu and the bioethicist Julian Koplin suggest that before such brains are brought into existence in research, it should be demonstrated that the study could not be performed, instead, on non-conscious brain organoids. Moreover, if uncertainty is present, then it is preferable to be over-cautious rather than underestimate their moral status. They explain:

> If these organoids develop sophisticated cognitive capacities beyond mere consciousness – if, for example, they display forms of self-awareness – we might want to attach extra weight to their interests, or even rule out harmful experimentation altogether.[178]

This is important because one relatively new idea in the development of neuronal interfaces takes the form of growing entire human neuronal systems in the laboratory on an array of noninvasive electrodes. This new 'human brain' could then be used, in a similar fashion to a computer, to direct other biological or electronic systems.[179] Such a possibility has already been studied using around 100,000 rodent brain cells on an array. But three-dimensional structures are also being developed that could significantly increase the number of neurons being used.[180]

Human neurons are also being cultured to form synthetic brains, allowing, according to Kevin Warwick, the possibility of 'a robot with a human neuron brain'. However, Warwick does acknowledge that: 'If this brain then consists of billions of neurons, many social and ethical questions will need to be asked.'[181] He suggests that this would especially be true if the robot had the same, or far more, human brain cells as a human being, which may then entitle this robot to human rights.[182]

Ethical Issues Relating to the Technology of Neuronal Interfaces

One of the most important ethical questions arising from neuronal interface appliances relates to their safety and whether the advantages outweigh the considerable risks that may be associated with such technology.[183] Furthermore, the motivation behind using these interfaces should be carefully examined to assess, for example, whether they can be considered as medical interventions and/or enhancements.[184] This is because a new procedure may be considered as an improvement in the context of medicine, but the same technology could also be used for other purposes, such as to enhance normal functions. For instance, the development of human vision beyond the range of what is normally visible would not generally be considered as a medical procedure, since this capacity has never previously existed in human beings. Questions can then be asked whether such an enhancement could be considered as beneficial for the individual, or for the whole of society, if it were possible, for instance, to make night driving a lot safer.

It is also important to consider the personal autonomy of an individual in choosing what risks to take in the context of a societal decision about which enhancement technologies to allow. This implies that if it can be shown that the risks arising from the enhancement are minimal, the burden of proof should generally lie on those who would argue that the enhancement should not be used. In the light of this, an important question relating to enhancement technologies is whether it would be possible to prepare guidelines and regulations concerning the kind of technology for which societal approval may be necessary, thereby restricting personal autonomy.[185]

Risks Related to Noninvasive Neuronal Interfaces

It is worth noting that with noninvasive output or input neuronal interface systems, such as EEG, some elements of risk remain. Amongst a number of challenges, this is because of the inherent plasticity of the brain with respect to function or structure as a result of interfaces requiring a highly repetitive use of certain applications. A lot of time may be required for a user to learn how to generate certain brain electrical signals in order to control a device. The performance of a user may also be dependent on how tired he or she feels, as well as any distractions or other external influences.[186] However, it should be recognised that in any learning process, such an effort is usually required.[187]

Risks Relating to Invasive Neuronal Interfaces

Ever since it has become possible to implant devices into the nervous systems of individuals, it has been necessary to consider the risks such applications create. Moreover, from the earliest analyses of these risks, it is clear that a consensus about what the unintended risks (or benefits) might be is difficult to find.[188]

Implanting a device, such as an electrode, into a certain brain area is very likely to have lasting effects. This is because once it becomes integrated into the tissue, its subsequent removal may give rise to serious damage. It is therefore important to consider whether better technologies may be available in the future and whether all the information about the optimum location for implanting the device has been provided to the prospective patient.[189]

Any activity in the brain will also cause other brain cells to migrate towards, and cluster around, the device. Indeed, some of these cells will recognise the implant as being foreign to the body and will then work hard to destroy or evict it. Furthermore, if an electrode is implanted, this clustering will most probably eventually interfere with its ability to pick up or give signals.[190] But much progress has been made in recent decades into developing materials that resist rejection. For instance, nanoscale coatings on surgical implants may give enhanced biocompatibility. However, it is still necessary to assess the risk of abrasion in long-term use and the possible release of nano-particles into the brain.

Connecting the device with the outside world also creates challenges. Implanting any item into brain tissue will cause local neuronal and vascular damage and will introduce an increased risk of infection.[191] The first devices all relied on wires reaching from the electrodes through the skin, but the exit site for these wires could give rise to possible infections, with the wires forming a surface along which bacteria can travel. Moreover, the wires themselves can easily act as aerials, picking up radio signals or electrical interference from the surrounding environment. If this occurs, the device may malfunction or the information it is transmitting may be lost in the midst of the 'noise'.[192] However, future wireless appliances may be able to partially address some of these challenges.

In normal situations, a person often has a number of different ways to help him or her communicate, such as talking, waving a hand or in more extreme situations blinking. If a person believes that others have misunderstood what he or she wanted, he or she can reinforce or correct the message by doing something. But in some situations where neuronal interfaces are used, such as when a person is locked-in, communication through the device may be the only means of conveying a message. If that information is disrupted through interference, then the person has no secondary means of correcting the situation.[193] Thus, a system linking a brain to a wheelchair would need to seriously consider a secondary safety system in order to prevent dangerous or unintended movements.

Biological risks relating to neuronal interfaces should also address the long-term consequences that may not be envisaged at the beginning. For example, it may eventually be necessary to remove a device because it became defective, less effective or worn out. This means that in the case of implants, reversibility and controllability are significant factors. If something goes wrong, it is important to consider whether the device could be taken out of a person, replaced with a new or more improved system, or even just deactivated.

On this account, when the medical conditions being considered are very serious, it may be acceptable for greater risks to be taken in implanting devices. The advantages of invasive and partially invasive output systems, with respect to the accuracy of recording brain signals, should then be examined against the considerable disadvantages that the person may already be experiencing.

However, in the context of enhancement, very different risk-benefit ratios would exist. Indeed, if the system was only a means of enhancing a normal situation, the risks would need to be minimal at best.[194] This means that invasive neuronal interfaces used for enhancement purposes may remain in the distant future.

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Chapter 5

CYBERNEUROETHICS

Because of an increasing understanding in the way in which the brain functions, the development of ever more powerful computers, and advances in neuronal interface systems, direct interactions between the brain and computers, and between the mind and cyberspace are slowly becoming a reality.

Of course, some of the present technology remains relatively crude and significant improvements will be required before more advanced neuronal interface appliances become available. But these will eventually be developed, which means that an anthropological and ethical examination of these appliances is necessary in the light of potential benefits for either therapy or enhancement while seeking to understand and address possible future risks or harms.

As the Parliamentary Assembly of the Council of Europe stated in 2017:

> The pervasiveness of new technologies and their applications is blurring the boundaries between human and machine, between online and offline activities, between the physical and the virtual world, between the natural and the artificial, and between reality and virtuality. Humankind is increasing its abilities by boosting them with the help of machines, robots and software . . . A shift has been made from the 'treated' human being to the 'repaired' human being, and what is now looming on the horizon is the 'augmented' human being.[1]

In this regard, it is recognised that any innovative biotechnical procedures will always involve new ethical challenges, such as seeking to balance the possible advantages against eventual drawbacks. These ethical hurdles will also have to consider the way in which a decision is made to use such procedures. These include whether legitimate reasons exist to limit individuals from making their own decisions, the manner in which they consent to unidentified risks to themselves and to others, and the consequences that the procedures may have for the whole of society. This may especially be the case with any procedure interfering with the brain, since it is closely associated with a person's sense of identify and self. In other words, any inadvertent changes to an individual's brain may have an effect on how he or she understands who he or she really is.

Moreover, since the short-term and long-term effects of such new interfaces are unknown, their personal and societal implications need to be carefully examined before being considered as ordinary applications.[2] In addition, because some benefits and harms may be more significant than others, the way in which these are balanced against each other may not always be straightforward. On this account, it is crucial to examine what importance should be given to each possible benefit and harm, while then making a judgement about their relative merits.

When considering harms, it is essential to note that terms such as 'minimal risk' may be understood in different ways. For example, it may imply a small risk to a large number of persons or a small risk of very serious harm to a few individuals. This means that it is not just the seriousness of the risk that matters, but also the probability of the harm actually occurring and whether a large number of persons would be affected.

Of course, with an increase in understanding of the brain and its functions, it may also become possible to better quantify and minimise any risks. However, some residual uncertainty will always remain about long-term use, though this is no different from other forms of biological interventions.[3]

One final aspect which should be considered is the way in which perceptions concerning a procedure, such as neuronal interfaces, may change over time. At first, they may be seen as new and ethically controversial, but over the years may become increasingly seen as normal, more commonplace and acceptable.

In the following sections, some of the individual and societal ethical challenges already arising from traditional interfaces with computers and cyberspace will be examined in order to put into context some of the new future possibilities that may arise from the development of direct neuronal interfaces. However, as will become evident, these new interfaces will give rise to far more sensitive ethical questions than actually exist with present technologies. For instance, in addition to the concerns over privacy that are already present with information technology, neuronal appliances may actually affect the very manner in which humanity may be understood as *Homo* *sapiens*. Moreover, these new questions may prove far more meaningful in framing the extremely important implications and consequences being suggested by the integration of the mind with cyberspace.

General Ethical Considerations Relating to Neuronal Interfaces

When new procedures such as neuronal interfaces are being considered for use, one of the first stages in examining their ethical aspects is to gather as much information as possible, while seeking to consider both the advantages and risks for all those involved, such as the individuals concerned and those in society.[4]

Individual Ethics

The first level of ethical examination may be related to the individuals who may be considering the use of neuronal interfaces for either therapeutic of enhancements reasons. In both of these categories, different risks and advantages will need to be balanced relating to how the appliance is used.

Advantages for Individuals

In examining the ways in which individual persons may benefit from neuronal interfaces, it is not only the number of benefits that should be considered, but also how these are perceived by the relevant person, which may be a more subjective affair and may vary according to his or her goals and aspirations.

Within this context, the first kinds of advantages that may be considered relating to such interfaces are 'positional benefits' and how a person may improve his or her position in a competitive society. In such an environment, any interface that may give a person an edge over his or her peers may be seen as beneficial. However, if everyone ends up using the same interface, no personal competitive advantage may remain, though benefits may still exist for society from such an overall improvement.

At the same time, more 'intrinsic benefits' may exist for individuals using neuronal interfaces that may go beyond what may be considered as purely competitive advantages. These may be life benefits that would be seen as being positive in themselves, such as being able to remember enjoyable past experiences. Similarly, 'instrumental benefits' may exist with neuronal interfaces, such as in term of being able to resolve complex problems that arise in a person's life or being able to remember facts and figures for work.[5]

Risks for Individuals

Any biomedical or biotechnological intervention generally involves some degree of risk, even if this may be relatively small. But when a treatment for a medical condition is being considered, these risks are generally seen as proportionate in light of the benefits.

In this respect, the first kind of risks that may arise from neuronal interfaces may be possible side-effects that should be carefully assessed, since some can be hidden, rare or long-term. Particular side-effects that may be relevant for children and young people should be thoroughly and meticulously examined since their brains are still developing. Indeed, they may benefit in the short term, but very real negative consequences may then appear later in their lives.

Furthermore, unintended consequences may exist. For instance, once a benefit is achieved using an interface, there may be increased pressure on the individual to continue using the appliance to maintain the same level of performance, leading to a likely increase in dependency and even addiction. Another possible unintended consequence is that pressures may increase on individuals to be connected all the time, to work harder, longer and more intensively. As a result, it could actually make life even more difficult than before. Thus, the risks of unanticipated negative side-effects may be significant, making it difficult to provide appropriate information to individuals so that they can make an informed decision.

Finally, when an individual considers using a neuronal interface, it may not just be a question of personal autonomy or consent alone that matters, since society may decide to limit informed and competent individuals taking certain risks. This may happen through, for example, setting standards, licensing practitioners and prohibiting procedures that are demonstrably dangerous.

Societal Ethics

The second level of consideration is related to the prospective risks and advantages to society. Again, an appropriate balancing of these will need to be carefully examined, which may not always be straightforward.

Advantages for Society

Because all individuals live in society, what may happen on a personal level may affect others in both a positive and a negative manner. This means that any individual use of neuronal interfaces may have an impact on society, for good or for ill.

In this regard, one possible societal benefit arising from such interfaces is the development of a more interactive and informed society. Of course, an individual linked to cyberspace in a more intimate way may not necessarily be more content with life and may still be socially inept. Nevertheless, if many in society have access to interfaces, this may enable them to have a better social life and be able to contact more people, while having access to immeasurable amounts of information.

Another benefit of neuronal implants for society is that they may support many traits of day-to-day life, such as concentration and memory, thereby addressing the limitation of human nature. A fairer society may also result from such appliances that may be used to reduce some of the inherent inequalities that may exist between individuals.

Furthermore, neuronal interfaces may enable individuals to achieve their full potential. Those with more limited access to information or those from deprived backgrounds could then begin to develop new skills.[6]

Risks for Society

But in the same way that potential societal benefits may arise from neuronal interfaces, risks may also exist that require consideration, such as their unintended effects on a community, in that individual risks may impact on society as a whole. For instance, an increased dependence on interfaces may sometimes cause psychological illnesses, which may go beyond the individual to his or her family and to the wider community in terms of the increased risks for social problems as well as costs. In the same way, any increase in expectations to work harder and longer has implications beyond the individual and may give rise to family discord and lead to conflicts. Thus, even though neuronal interfaces may be seen as very useful to many individuals, a society also needs individuals to be caring, cooperative and attentive to the needs of others.[7]

Another concern about the use of such interfaces relates to the risk of coercion and experiencing pressure in a community to use a device, in that what may begin as an individual and free decision may very quickly become expected and even demanded by society. Vulnerable individuals may then be subject to peer pressure to use the devices in order to become part of the social group, with the possibility of experiencing stigmatisation if they refuse.

Such risks of coercion are especially important in the context of interventions on the brain that may affect aspects of an individual's personality and even the very nature of society if there are a large number of users. Neuronal interfaces may then alter the basic fabric of human life.

If certain interfaces came to be seen as essential for public life, some political leaders may also be tempted to consider them for use at the national level or may even impose their use if they believe they could bring greater benefits to society. This has already happened, for example, with certain immunisation programmes in some countries.[8] There might even be a strong public interest argument in making neuronal interfaces compulsory if it could be demonstrated that such appliances may lead to a more stable society.

It is also worth noting that the potential military use of neuronal applications is already of interest to national defence agencies seeking to maximise the performance of soldiers. As a result, this may mean that if such interfaces are available to one side in a conflict, pressure will mount for others to have them as well.[9]

The Risk of Increasing Inequality in Society

A final risk for society arising from neuronal interfaces that may need further discussion is that they may actually increase inequality. Indeed, whilst such interfaces may bring certain benefits to individuals, they may also accentuate a competitive and individualistic success culture, which may be detrimental to the cohesion of a fair and descent society within which everyone can flourish. Moreover, at least initially, it is likely that the appliances may only be available to those who are willing and able to pay.

The fairness argument focuses on the future of society and recognises that, for good or for ill, financial resources are not usually spread evenly across the general public.[10] Consequently, some individuals may be unable to afford any or only certain neuronal interface enhancements. As with all technological developments, the cost would certainly exceed what some people could afford. Thus, unless limited to those who had the appropriate means, the interfaces could become a serious financial drain on the resources of an already fragile economy. Moreover, the financial intervention of healthcare providers introduces other interested parties into the already complex web of professional bodies with a stake in interfaces.

More seriously, however, the cost of the neuronal interfaces may lead to inequalities amongst future individuals. But in some respects, this unfairness already exists in many other areas of public life. Any individual who accepts the right of parents to put their children into an expensive private school or hospital cannot really use the fairness argument as a reason for rejecting the use of neuronal interfaces. Nevertheless, the central point of this fairness argument emphasises that these inequalities should not be strengthened or encouraged in any way. Indeed, the sufferings of the poor may be multiplied by the use of neuronal interface enhancements, since they would have to contend with technological discrimination in addition to the limitations that they already experience because of their economic situation.[11] An example of such an outcome was presented by the American author Matthew Anderson in his 2002 science-fiction novel *Feed*, which depicts some of the forms of discrimination and limitations that may exist for those who do not have the latest versions of neuronal interfaces.[12]

In response to this form of the fairness argument, it has been suggested that inequality is not necessarily always detrimental to society, since a measure of unfairness may actually give rise to some advantages, such as a sense of competitiveness. In short, a certain measure of inequality should not always be the basis for alarm.[13] Yet, in pleading for an acceptable disparity, this proposal may mean limiting certain neuronal interfaces, which should be available for all, to only a few privileged individuals, which would no longer be seen as beneficent.

Another response to this form of fairness argument recognises that humanity is already divided. For example, people are already categorised on the basis of whether they are infected with HIV/AIDS or whether they have clean drinking water. But it is difficult to imagine a compassionate and rational person objecting to providing help for the sick unless a treatment were available to all who needed it. For instance, if a cure for HIV/AIDS became available, with enough doses for only 10 per cent of the over 30 million people with the disease, only very few (if any) would object to distributing this treatment to only this 10 per cent of patients. In other words, even though an action may seem unfair, it may still help some individuals. By this reasoning, the fairness argument is weakened because aiding individuals through neuronal interfaces is preferable to not helping anyone.

The increasing costs of producing new neuronal interfaces may also exacerbate the differences between individuals who can afford to acquire advantages in a competitive environment and those who are too poor to afford them. But, as already indicated, this situation is not new, since the wealthy already have a number of real advantages. Yet, a lot depends on the rest of the assumed social and political contexts. This means that the introduction of neuronal interfaces into a society may only be of concern if it did not already have procedures in place seeking to redress any inegalitarian tendencies. If neuronal interfaces eventually gave rise to a small elite group of privileged persons who flaunted and enjoyed their superiority, disregarding the rest of society, then it is doubtful whether the majority (those not in the elite) would assess the situation positively.[14] Moreover, this form of unfairness may be compounded, since the resources devoted to the enhancement of the elite would very likely be diverted from aiding the poor. In order to address this imbalance, society may decide to restrict neuronal interface enhancement, though creating and justifying feasible mechanisms for such restrictions may pose significant challenges.

Online Humans

In an interesting short science-fiction story entitled 'The Machine Stops',[15] written in 1909, the English novelist Edward Forster (1879–1970) described a world in which most human individuals live underground in nearly complete isolation, each within his or her own small standardised room. Nearly all real face-to-face communication between individuals is avoided and seen as uncomfortable.

An omnipotent, global Machine takes care of every physical and spiritual requirement, while enabling communication to take place between individuals through a kind of instant messaging and video monitor. This is constantly being used by all the solitary persons, in their cells, to recount experiences that none of them has ever lived, first-hand, in the real world above ground. But eventually, and even though religion is frowned upon, the Machine slowly becomes an object of worship, with those rejecting its deification being threatened with 'Homelessness'. However, very few are willing to acknowledge that the Machine is beginning to break down.

In a way, this story can be seen as a predictive parable of what is already beginning to happen in modern society. Here as well, it is now possible to find many persons in front of their computers with their earplugs in their ears, completely isolated from face-to-face relationships while increasingly spending large amounts of time online.

The web and social media both increase and decrease the directness between persons. An individual can now communicate with someone, or even with many people, he or she would not otherwise have been able to reach. But this communication may often just be characterised as an 'interaction' rather than a 'relationship'. It may be somewhat superficial and may lack the quality of a face-to-face, physical encounter, including voice tone, body language and expression.[16]

Moreover, it is a trend that is unlikely to stop. Thus, some of the first elements of cyberneuroethics that may need to be examined are the real risks and also advantages of hyper-connectivity.

Hyper-connectivity

The term 'hyper-connectivity' characterises the use of multiple communication systems and devices enabling a person to remain highly connected, in real time, to social networks and streams of information. It also includes the possibility of being able to record a person's communications or exchanges, enabling him or her to document his or her life.[17]

Ever since the beginning of the twenty-first century, an increasing number of persons have been able to access the Internet.[18] At the same time, the growing use of mobile smartphones has meant that individuals can, if they so wish, be constantly connected to each other and to this network. Already by 2011, there were more devices connected to the Internet than there were people in the world.[19]

In this regard, younger people seem more likely to make use of Internet-based communications, with a 2011 survey in the United Kingdom noting that, amongst 16–24 year olds, 45 per cent indicated that they felt happy when they were online, 86 per cent felt that the new technology helped them communicate with people and 96% said that they accessed another media device such as a mobile phone while using the Internet.[20]

But in spite of these trends in hyper-connectivity, a number of households are choosing not to access the Internet for various reasons. There is also a minority of about 10 per cent (aged 17–23) who define themselves as lapsed Internet users by limiting home access and restricting resources.[21]

However, it is worth noting that things can get out of control in some rare instances. For example, a young 28-year-old South Korean man was reported to have died in 2005 after playing the online computer game *Starcraft* at an Internet cafe for fifty hours with very few breaks. The police indicated that the man had not slept properly and had eaten very little during his marathon session.[22] This reflects a real risk that players may no longer contemplate doing anything else, which they consider less interesting, than their games – an outlook that may represent a real challenge for an appropriate integration into society.

Because of such risks, and in order to address the dangers of hyper-connectivity (and especially amongst young people), the South Korean Parliament eventually enacted the Shutdown law (also known as the Cinderella law) in 2011. This prohibited children under the age of sixteen playing online video games between midnight and six in the morning on the next day.[23]

Coping with the Amount of Information Available

Since many more people are spending increasingly more time on the Internet than before, new adverse consequences are beginning to develop. For instance, individuals may no longer be able to cope with the amount of information available, thereby increasing stress and leading them to abandon certain tasks. Questions can be asked as to whether individuals in society need to know so much. Uncertainty also exists about the manner in which pupils in schools will process the amount of information they are given and how education systems may have to change. Indeed, it may be impossible to compartmentalise the information received so that a person can use it in an appropriate and ordered way.

Individuals may have to become increasingly selective and disregard what they cannot use or understand. They may need to learn to prioritise and develop their reliance on others for potted versions of information, while at the same time remembering how to access that information when it is needed.

For individuals who spend a large proportion of their time connected to the Internet, various further challenges may arise. For example, quickly flicking between many topics may undermine an individual's ability to concentrate. A 2009 Stanford University study in the United States concluded that individuals who are regularly confronted with several streams of electronic information cannot pay attention, control their memory or switch from one job to another as well as those who prefer to complete one task at a time.[24] The American academic and communication expert Clifford Nass (1958–2013) explains that 'They're suckers for irrelevancy' and 'Everything distracts them',[25] with Nass' colleague, the psychologist Anthony Wagner, explaining: 'When they're in situations where there are multiple sources of information coming from the external world or emerging out of memory, they're not able to filter out what's not relevant to their current goal . . . That failure to filter means they're slowed down by that irrelevant information.'[26]

Individuals who spend a lot of time online may also find it increasingly difficult to compartmentalise different parts of their lives, such as work and family life. As such, it may be more difficult for them to maintain boundaries between online and offline identities. Because of the amount of time needed to access all the websites, some have even suggested using the web to support other activities, such as using audio electronic books to tell stories to their children in order to save time for themselves.

Another challenge is the use of email to contact individuals about work matters during leisure time. This breakdown between a person's professional and private life could make it more difficult for employees to set limits and may be one of the most important and transformative consequences of social and technological changes.[27] For instance, if individuals decide not to switch off their work mobile phones at home, they may end up working all the time. Because of this, France decided to introduce new rules in 2016 to protect people working in the digital and consultancy sectors from work emails outside of office hours. The deal signed between the employers' federation and trade unions indicates that employees will have to switch off work phones and avoid looking at work email, while firms cannot pressure staff to check messages.[28]

However, an advertising professional who moved from London to New York describes a different email culture from that found in France:

> I remember on my second day seeing an email from a work colleague sent very late that evening. To my surprise someone replied to it, and then the interac-

> tion continued online. And lo and behold we 'were working'. By contrast, in the UK, if I worked late I would often draft emails but save them in my inbox and send them first thing the next morning. That now seems ridiculous and archaic to me. Emails are constant here. It's not that they expect you to answer out of office hours. More that everyone is 'switched on' all the time – that's the culture and pace of New York. I never really heard the concept of work/life balance when I got to the US. There wasn't much complaining as people's expectations were different. It's not just in the corporate world. When my family were moving here and trying to get an apartment I remember being surprised and delighted that our realtor was calling and emailing us late on a Saturday night.[29]

Concern also exists about the overwhelming effects of a constant stream of information. The apparent need for some persons to be permanently online in order to interact with programmes and other persons through social networks is increasingly becoming a problem. Experts are worried that addiction to new technology is having a negative psychological impact, causing anxiety when a device is not accessible.[30]

In 2008, the U.K. Post Office commissioned a research study that coined the term 'nomophobia' (short for 'no mobile phobia') to describe the stress and panic arising from a lack of mobile connectivity. The study found that 53 per cent of mobile phone users developed significant anxiety when their phone was lost, out of network coverage or out of battery. However, it was suggested that this obsession with new technology may be reduced as the novelty wore off,[31] although, more recently, a new type of social anxiety called 'Fear of Missing Out' (FoMO) has been described. This is defined as an individual's fear that others may be having rewarding experiences that he or she is missing out on. It is also expressed in a desire to stay permanently connected to sources of information about what others are doing. As a result, there seemed to be an inability by some affected by FoMO to commit to anything out of a fear of having to change their plans in order to not miss out.[32]

It is further recognised that some games can be somewhat addictive to certain players when they are constantly being challenged and rewarded while moving through the skill levels that reinforce the player's attention. But, at the same time, being permanently immersed in a fictional virtual world may reduce a player's interest in dealing with people in the external real world and may even encourage him or her to escape the difficulties of this world.

On a more calamitous note, concerns also exist that the whole electronic system may eventually shut down in a catastrophic collapse, making it impossible for individuals to access their information on which they have become so dependent. If ever a future cyber-attack took place, with all cyber-communication breaking down, the consequences would be monumental.

But, of course, there are also advantages in being connected to cyberspace. The Internet gives access to a large volume of useful and practical information, such as books and articles. Some may even feel a sense of reward from gaining an ever-increasing amount of such information. Improved access to the Internet may also allow individuals to keep in touch more easily and frequently with family and friends.[33] This means that events that occur elsewhere in the world can have an immediate impact on persons.[34]

In short, when considering the possible risks and advantages of hyper-connectivity to the Internet, it should be recognised that this is already part of modern life. This means that if a direct neuronal interface eventually becomes available, accessing cyberspace through the mind of a person may just continue on a trend that has already started. Many more individuals may then increasingly spend ever more time in cyberspace, which may eventually become the 'normal' space in which to interact with others because it may be far more attractive than the 'real' space of reality.

Virtual Worlds

As already mentioned, an increasing engagement in virtual worlds is already developing in modern society. This makes it possible to define three general types of virtual reality, depending on how much the user may perceive and engage with the virtual world:[35]

– fully immersive (with head-mounted and other devices attached to the body);
– semi-immersive (with large projection screens); and
– non-immersive, such as using a personal computer.

The above classification is characterised by the level of immersion in the virtual world, with non-immersive virtual worlds influencing a larger proportion of the population, at present, than more immersive forms of virtual reality.

Within virtual worlds, it is also possible to recognise two categories, with ludic virtual worlds describing rule-based games involving direct competition between players, and paidic worlds promoting free play and creativity, with less emphasis on rule-constrained competition.[36]

One of the most popular examples of the paidic type of virtual worlds is the already-mentioned *Second Life*. Although joining this world is free, users often need to purchase items using a virtual currency called Linden dollars. In this way, it is possible to buy clothes or sell houses for other people's avatars. There is even an exchange rate with the U.S. dollar.[37]

The attraction of spending time on *Second Life* is that persons are able to set aside their problems in the real world and instead change their reality, such as their looks or buy a house, car and clothes that they could never afford in real life. *Second Life* also enables users to make meaningful relationships that may be based on a projected self and common interests. In real life, individuals are subject to many experiences that are outside of their control. In the virtual world, on the other hand, they are delivered from these limitations and success is easier to attain.

Already, for certain individuals, the virtual world may develop into an end in itself – the preferred place in life. It has even been predicted that the real world will have to change if it wants to lure these people out of their virtual worlds and back into being fully participating members of society.[38]

But there are also challenges for the future of *Second Life*.[39] For example, the Linden Research, Inc. company that created *Second Life* has now downsized and is focusing on users selling virtual goods to each other.[40] Nevertheless, increasing numbers are still using the website, demonstrating that many individuals find their experience in the virtual world to be beneficial. Indeed, a person who plays a virtual reality game and who feels a sense of unity and interaction with other players may see this as being far more positive than just passively watching television on his or her own.

That being said, nobody is certain in which direction all this will go. By examining the way in which real and virtual realities may interact in the future, the American author Michael Heim indicated that: 'With its virtual environments and simulated worlds, cyberspace is a metaphysical laboratory, a tool for examining our very sense of reality.'[41] However, it is worth noting that virtual worlds are not in any way new, since many individuals have often sought refuge in the fantasy world of books. Therefore, there may not be any serious consequences as a result of spending time in cyberspace – it may just be a question of balance.

Social Media

In contrast to traditional communication technologies, social media enables a person to create, share, consume and collaborate in many new ways.[42] Online social media has seen a surge in usage in recent years, becoming one of the most commonly used activities for a majority of those in countries such as the United Kingdom.[43]

However, in the future – and though it is difficult to predict – the nature and use of online appliances may change radically,[44] creating concerns about how online identities could be controlled and how ownership can be regulated. Further questions relating to the use of personal content and whether this can remain a private matter may be asked.[45]

One possible use of social media, for example, is the development of more political activism using networks that may become influential in 'spreading the message' and allowing instant feedback and commentary.[46] Recently, social media has been used to facilitate political movements such as the revolution in Tunisia in 2011 and in mobilising dissent in Egypt and Libya, though the extent of its influence in these countries has also been questioned.[47]

Responses to These New Technologies

In 2012, a discussion article between the British scientist, writer and broadcaster Baroness Susan Greenfield and the Bulgarian writer, blogger and critic Maria Popova was published in the *New York Times* entitled: 'Are We Becoming Cyborgs?' This considered the relentless development in the use of the Internet, which had already reached one-third of all human beings on the planet, with the average amount of time spent online by all persons of the world representing about 16 hours per week and rising. Thus, human beings are continuing to change the way they interact and, as a result, their very characteristics as social beings.[48] This means that as neuronal interface systems create new associations between the real and virtual worlds, ethical and anthropological questions can be asked in relation to whether they will eventually encourage a 'dematerisalisation' or even a 'virtualisation' of human life.[49]

Greenfield expressed concerns that the current electronic appliances were now dominant in the lives of children in contrast to other technologies. On this account, it was not the technologies in themselves that created anxiety, but the degree to which they were becoming a lifestyle rather than a means to improving a life.

Human brains are exquisitely evolved to adapt to the environment in which they are placed. Greenfield notes that every hour spent sitting in front of a screen is an hour lost talking to someone or being outside in the sunshine. She is concerned about how this may impact on social relationships arguing: 'If virtual friends replace flesh-and-blood ones, we shall not need to learn social skills, not think about the unwanted and unpredictable reactions of others.'[50]

Popova, on the other hand, expressed unease about the tendency to conflate information and knowledge, indicating that ultimately knowledge is an understanding of how different elements of information fit together. There is an element of correlation and interpretation. But while it is possible to automate the retrieving of knowledge, it may not be feasible to automate the making of moral decisions based on this knowledge and giving it meaning.

However, at this stage, the consequences of neuronal interfaces on the cognition of a person may need to be examined.

Changing Cognition

The term 'cognition' originates from the Latin verb 'to learn' and reflects a group of mental processes that includes attention, memory, producing and understanding language, learning, reasoning, problem-solving and decision-making. This means that in examining the concept of cognition, it is usually necessary to have an interdisciplinary perspective, including aspects of psychology, cognitive science, neuroscience and sometimes also computational neuroscience, artificial intelligence, autonomous robotics, computer vision and other areas.

In other words, the cognitive components of systems, such as neuronal interface systems, cannot be designed and studied in isolation; they have to be examined in the light of their potential association to sensorimotor systems and by the adaptation of cognitive systems to particular physical and task environments.[51] In this respect, artificial cognitive systems are usually considered to achieve human-like cognitive competences, such as making sense of the world through perception, organising thought and acting in the world in meaningful ways.[52]

Moreover, what is often examined are the possible positive changes to the cognitive faculties of an individual. These are generally termed cognitive enhancements and can be defined as 'any augmentation of core information processing systems in the brain, including the mechanism underlying perception, attention, conceptualization, memory, reasoning and motor performance'.[53]

Of course, such enhancements include some of the oldest forms of human improvement and are generally seen as attractive. But while chemical cognitive enhancers such as caffeine are already being used widely by many societies,[54] new technologies are now being considered, particularly in the realm of neuronal interfaces with computers and artificial intelligence.

In this context, neurocognitive appliances would be able to sense or modulate neuronal function in order to physically augment cognitive processes such as executive function, attention and memory. Neuronal interface systems may also be able to improve wakefulness, perception, moods and social or moral cognition.[55] Similarly, eliminating the retention of distressing memories could be considered as a kind of functional advancement.[56]

At this stage, it is important to remember that many of the ethical questions raised by cognitive treatments and enhancements using neuronal interfaces may be similar to those that already exist in, for example, the use of certain pharmaceutical drugs. As the Presidential Commission of the Study of Bioethical Issues indicated in 2015:

> The debates about cognitive enhancement include many of the ethical concerns raised by neural modification more generally, including the importance

> of facilitating healthy development and wellbeing; respecting moral agency; informed consent to medical procedures and research; minimization of risk; public education and deliberation; equity and access across all demographic groups; and the reduction of disadvantage, suffering, and stigma associated with neurological disorders.[57]

Using neuronal interfaces to change the cognitive aspects of a person is only just beginning to be considered by neuroscientists, and the following chapter can, therefore, only be seen as an introduction to this complex area. But the important areas of intelligence and free will necessitate further examination, as these have important implications on many other areas of cognition. Moreover, it should be remembered that knowledge, understanding and intelligence are not synonymous.

Changing Intelligence

The term 'intelligence' originates from the Latin verb *intelligere* 'to choose between' or 'to discern'. But no single definition of intelligence exists and it has been described in many different ways. However, it does include concepts of logic, abstract thought, understanding, self-awareness, communication, learning, emotional knowledge, retaining, planning, and problem-solving. In this context, many of the tests measuring general intelligence include the following ten characteristics:[58]

1. Fluid intelligence: includes the general ability to reason, form concepts and solve problems using new information or procedures.
2. Crystallised intelligence: includes a person's acquired knowledge, the ability to communicate this knowledge and the ability to reason using already learned experiences or procedures.
3. Quantitative reasoning: the ability to understand numerical concepts and relationships and to manipulate numerical symbols.
4. Reading and writing ability: includes basic reading and writing skills.
5. Short-term memory: includes the ability to understand and keep information in the present time so that it can be used in the immediate future.
6. Long-term memory: includes the ability to store information and retrieve it quickly in the longer term.
7. Visual processing: reflects the ability to perceive, analyse, synthesise and reason using visual patterns, including the ability to store and recall visual images.
8. Auditory processing: includes the ability to analyse, synthesise and distinguish sounds, such as the ability to process and distinguish speech sounds that may be presented under distorted conditions.

9. Processing speed: the ability to perform cognitive tasks quickly.
10. Decision and reaction speed: reflects the speed in which an individual can react to stimuli or a task.

In many of these areas, it may be possible for a person to improve his or her intelligence if it became feasible for a neuronal interface to be appropriately used with a computer. However, this then raises the question whether this should be considered and for whom. For example, it may be suggested that a responsibility exists for all individuals to increase aspects of their intelligence. But, on the other hand, it is possible to accept that only an increase in the mental faculties of persons who have a mental disability (though it may also depend on the disability) should be contemplated. This is because individuals should only be able to make progress in certain areas to the level that is considered normal (with the concept of 'normal' having to be defined).

As a result, it has been suggested that access to neuronal implants for certain cognitive functions should be used, in priority, for: [59]

– bringing children or adults into the normal range for the population, if the appropriate consent is obtained; or
– improving health prospects that should be based on need rather than on economic resources or social position.

With the possible development of neuronal implants for cognitive functions, another ethical concern is the risk of a two-class society emerging or an increase in the gap between industrialised countries and the rest of the world.

Changing Memory

Memories are vital in the life of individuals and enable them to function from a personal and societal perspective. In many ways, these memories seem to be solid objects in the minds of these persons similar to documents that can be called up and investigated, though at the same time they can be considered as ethereal. Memories are also central to personal identity, enabling persons to have a sense of self while remembering past experiences and building on them. It provides them with the continuity of self-awareness across their lives. The English philosopher John Locke (1632–1704) suggested something similar in his book entitled *An Essay Concerning Human Understanding* (1690). In this he indicates that a person is 'a thinking intelligent being, that has reason and reflection, and can consider itself as itself, the same thinking thing, in different times and places; which it does only by that consciousness which is inseparable from thinking'.[60]

Thus, for Locke, because consciousness of different times can be equated with memory, the existence of memory in an individual is a necessary condition of personal identity. For him, 'as far as this consciousness can be extended backwards, to any past action or thought, so far reaches the identity of that person; it is the same self now, it was then; and it is by the same self with this present one, that now reflects on it, that that action was done'.[61]

However, what a memory is in terms of its physical reality in the brain remains elusive. Psychologists can demonstrate how memories can be manipulated, created and falsified, but understanding the biological science behind these memories is still in its infancy, although it is accepted that they are made up of many elements, which are stored in different parts of the brain.

As already indicated, neurons propagate signals through a combination of electrical pulses that are sent down fibre-like extensions to the point where each neuron touches and connects with another neuron (a synapse). All the action in the brain of an individual occurs at these synapses, where electrical pulses carrying messages are transferred across the gaps between cells. This means that although a memory begins with perception, it is encoded and stored using the language of electricity and chemicals with the connections between brain cells being readily created and changed. They are not fixed and, as messages are sent through these connections, the fine structure of the brain changes slightly. In other words, as each new experience is recorded in a brain, it is slightly rewired. This plasticity is a key part in the brain's normal daily work, but it can also help the neurons rewire themselves if they are damaged.

Furthermore, if the same message is repeated a number of times in the brain, more signals are sent between the neurons and the connection grows. When, for example, a person hears a song, he or she may remember some part of it. If, on the other hand, the song is played repeatedly, it will be more firmly lodged in the memory of the individual. In this way, memories are stored in innumerable cells and synapses, with the brain organising and reorganising itself with every new experience.

Neurons in the brain analyse all of the inputs from a person's sensory organs, such as eyes, ears, taste buds and touch sensors. Their first 'decision' is whether or not the input is worth remembering. Indeed, the brain deliberately ignores vast amounts of information that it receives so that a person does not quickly become overwhelmed.[62] Different types of sensory input then get directed to different parts of the brain where each is stored. How they are pulled back together is, at present, poorly understood.

In short, it is very important at this stage to not exaggerate scientists' understanding of the functioning brain. It is one thing to recognise that neurons reconfigure their network and reposition their synapses as a way of storing information, but it is quite another to look at an interconnected set of neurons and make any deductions about the information stored.

Certain mental disorders reveal that there are two basic types of memory: short and long term. Some older people may be unable to remember the present date, forgetting the answer almost as soon as it is given, but though their short-term capability has all but gone, their long-term memory may still be functioning. Many find the loss of short-term memory deeply frustrating, but the loss of long-term memory could be far more distressing, since it may be associated with a loss of identity and a failure to keep hold of a sense of self.

Certain past memories may also help a person shape and form responses to similar situations in the future. This means that if certain memories are removed, the person may lose the necessary information that would enable him or her to react to future situations. For instance, with a mental disorder, such as Alzheimer's disease, certain areas of the brain become damaged. Their function is often difficult to define, though they are recognised as being crucial for long-term memory and the process of learning.[63]

In such situations, scientists are proposing that an electronic memory chip could be implanted into the brain in order to replace damaged memory functions.[64] In the future, it is even suggested that individuals could consider such memory implants in a positive manner because of their ability to bring back lost thinking processes.[65]

Whether such a direct neuronal interface system would ever be successful is an open question, but millions of dollars have already been invested by the U.S. Defense Advanced Research Projects Administration (DARPA) to undertake research into restoring such lost memory functions.[66] But DARPA has also expressed a need to restrict the memories of soldiers during horrendous combat situations in order to put them beyond the reach of post-traumatic stress disorder. Such interfaces could then eliminate or strictly control negative emotions, enabling the training of 'guilt-free', remorseless soldiers.[67]

In this regard, one of DARPA's main projects with neuronal implants is the Reorganization and Plasticity to Accelerate Injury Recovery (REPAIR) programme, which has the aim of using computer chips implanted in the human brain to directly alter its information-processing functions.[68] In this way, a person's memories, thoughts and especially emotions could be modified by direct neuronal control.[69]

DARPA's mission in this area began under the leadership of the American Tony Tether, who headed the agency from 2001 to 2009.[70] He unashamedly invited society to seriously consider such an enhanced soldier by exclaiming: 'Imagine a warrior with the intellect of a human and the immorality of a machine.'[71]

But neuronal interfaces affecting memory are not only being restricted to medical or defence considerations. This is because human beings know that their memories are often limited by the amount of information that can be stored. As a result, many are becoming ever more dependent on other means, such as technological devices, to retain their data. The American futurologist Ray Kurzweil even notes that 'we have already largely outsourced our historical, intellectual, social and personal memories to our devices and the cloud'.[72] It has also been suggested that individuals should be entitled to control their emotional life by eliminating or restricting negative emotions, such as guilt, sadness, fear and grief.[73]

Yet, when such memory chip implants are considered, real conceptual and ethical concerns arise as to their effects on personal identity if an individual wants to forget or remember some memories. For example, it may be possible for memory prosthetics to store information that a patient may not want to keep.[74] As already mentioned, memories support the very identity of persons and the way in which they see themselves, which means that any modification of these memories may result in serious questions being asked by these individuals about who they really are![75] This was the idea behind the 2004 science-fiction film *Eternal Sunshine of the Spotless Mind*, directed by the Frenchman Michel Gondry, which tells the story of an estranged couple who sought to erase each other from their memories.

Network Intelligence

With the development of direct neuronal interfaces, another outcome that may arise is the eventual combination, in some way, of the intelligence of a multiple number of persons in a form of network intelligence or hive mind. This could happen if it was possible for individuals to directly communicate their thoughts and memories using an interface or if human beings could upload the full contents of their minds and combine them in cyberspace.

Though such an outcome should be viewed with considerable scepticism, Kurzweil indicated that humanity could then reach the 'Singularity'. This is where the intelligence arising from a network of human minds, supported by computers, would lead to advances so rapid that the pace of change would dramatically increase to almost an instant.

Kurzweil presents the Singularity as an event taking place at about the year 2045, which is sucking humanity towards itself, much as a black hole sucks in matter and energy.[76] He describes this Singularity as a point in time in the future that 'will represent the culmination of the merger of our biological thinking and existence with our technology, resulting in a world that is still human but that transcends our biological roots'. In this world, 'there will be no distinction . . . between human and machine or between physical and virtual reality'.[77]

Kurzweil further indicates that at this Singularity, there will be 'a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed'.[78] This would mean that individual biological brains, as such, would no longer be necessary, since most of the 'intelligence' would be transferred into computers and much of the 'thinking' into cyberspace.[79] Kurzweil predicts that by the end of the twenty-first century, 'human' computer intelligence will be comparatively more powerful than its unaided biological equivalent.[80] Neuronal networks will have been replaced by electronic circuits that are far more efficient than the workings of a biological brain, while being entirely immune from disease.[81] However, he does admit that this massively intelligent mind will remain human, though it will be non-biological. At the Singularity, Kurzweil further explains that:

> We can imagine the possibility of our future intelligence spreading into other universes . . . This could potentially allow our future intelligence to go beyond any limits. If we gained the ability to create and colonize other universes . . . our intelligence would ultimately be capable of exceeding any specific finite level.[82]

He adds that:

> Ultimately, the entire universe will become saturated with our intelligence. This is the destiny of the universe. We will determine our own fate rather than having it determined by the current 'dumb' simple, machinelike forces that rules celestial mechanics.[83]

The language is full of hope and sounds victorious, but it is possible to question whether such an unlikely reality would actually be so positive. The English theoretical physicist Stephen Hawking indicates in this regard that:

> The danger is real that this computer intelligence will develop and take over the world. We must develop as quickly as possible technologies that make possible a direct connection between the brain and computer, so that artificial brains contribute to human intelligence rather than opposing it.[84]

What this would then mean for anthropology and the way in which 'humanity' would be defined in the future will be considered later in this book.

Free Will and Moral Responsibility

Progress in brain research is enabling scientists to better understand the way in which connections in the brain affect higher brain functions, such as decision-making. These studies suggest that the development of complex nervous systems is the result of a continuous, self-organising process, with close relationships existing between particular brain structures and specific brain functions.[85]

These close relationships have been demonstrated in clinical studies through the loss of specific functions following structural damage. In addition, noninvasive neuroimaging has shown that personal decisions and emotions are preceded by the activation of defined networks of neurons.[86] This means that both at the subconscious and conscious levels, human perceptions, reasoning, decision-making, planning, thoughts, arguments and value assignments are influenced by neurological states and developments.[87]

But does this then mean that all the thoughts of an individual are only caused and controlled by his or her brain? Or do human beings still have free will?

The debate relating to free will, and what this represents, has been around for millennia, having been of interest to philosophers, theologians, lawyers, ethicists and many others in various disciplines. One of the first times this was expressed was in the story of the mythical Greek king Oedipus recorded by the ancient Greek tragedian Sophocles (ca. 497/496 BCE – 406/405 BCE). In the legend, Oedipus seems to have been imprisoned by his destiny to fulfil a prophecy that predicted that he would kill his father and marry his mother, thus bringing disaster on his city and family.

Another example where free will was examined was in the 1956 book *The Minority Report* written by the American science-fiction writer Philip Dick (1928–82), which was made into a film of the same name by the American Steven Spielberg in 2002. This recounted the way in which the police sought to arrest individuals before they had committed a crime by reading their minds.

For a person to be a free agent with free will means that he or she has the ability to initiate and execute plans of action. More specifically, this includes motivational, cognitive, affective and physical capacities that enable a person to shape and translate mental states such as desires, beliefs, emotions, reasons and intentions into voluntary actions. The person experiences a sense of being in control of what he or she does.

The concept of persons being free agents is also at the heart of how human beings understand themselves as persons and what it means to be conscious, thinking and moral agents.[88] In 2015, the U.S. Presidential Commission of the Study of Bioethical Issues defined such moral agents as 'individuals capable of acting freely and making judgments for which they can be praised, blamed, or held responsible'.[89]

At the same time, however, agreement exists that free will experiences necessarily depend on human brain functions and that when some functional abilities are limited, for whatever reason, this can diminish or influence the will of a person. In addition, it is important to consider the significant environmental, cultural and historical influences that affect the brain and the mind.[90] For example, a person's behaviour and free will can be influenced by having a clinical depression that may affect his or her ability to frame and enact his or her intentions.[91]

More generally, it is worth noting that no human person has complete control of his or her actions. This is because many effects, including unconscious biological processes in the brain, are involved when a decision is made.[92] For instance, it is only when the brain becomes aware of the feeling of hunger that a person begins to behave in a certain way by looking for food.

It is also accepted that the mechanics of the nervous system can sometimes have a real effect on a person's decision-making capacity. If a person commits a serious crime in order to obtain some benefit and a tumour is then discovered in his or her brain, extenuating conditions may be accepted by a court. A brain tumour has indeed been demonstrated to disrupt certain neuronal pathways associated with moral behaviour and inhibitory centres that would normally prevent inappropriate actions. This means that free will may be affected by neurobiology, even though the persons themselves may believe that they are totally in charge and that their behaviour is not being influenced by any effects in their brains.

Research suggests that persons are aware of only a minuscule fraction of the neuronal activities that regulate their behaviour. Some signals are, in fact, always ignored by the conscious person, such as those that manage blood glucose levels. Similarly, other brain signals that control certain forms of behaviour are processed without the knowledge of the person.

In parallel to this unconscious form of performance, conscious reflection and deliberation can take place. This happens if a person gives reasons for an action for which he or she is consciously aware. However, a significant amount of brain activity that actually prepares and determines the decision remains outside of conscious recollection.[93] This means that the subconscious and conscious parts of decision-making are both acting together in determining behaviour.

In a similar manner, a memory device implanted in the brain of a person who remains unconscious of its operations may not necessarily undermine any concept of this person's free will and agency. If an individual is not in total control of his or her thoughts and behaviour, this does not mean that he or she may not be acting freely.

Though no unanimity exists, philosophers generally believe that three overall conditions are necessary for persons to have free will, namely, that they must:

1. have different alternative possibilities from which to choose and to act;
2. have a responsiveness to reasons for appropriate actions; and
3. be the original and internal source or authors of any actions.[94]

It is also important that persons have the possibility to bring about whichever of the options they will, when they want, for the reasons they want, without being coerced or compelled in doing so, or otherwise controlled by other agents or mechanisms.[95] Likewise, the American legal philosopher Robert Kane indicated that free will involves 'the power of agents to be the ultimate creators (or originators) and sustainers of their own ends and purposes'.[96] This entails the ability for persons to critically think through their desires, beliefs, reasons, as well as their intentions, and either reject or endorse them as the free authors of their actions.[97] The will is then the effective desire that moves a person all the way to action without further consultation with any possible higher-order desires.[98]

In this regard, the political scientists Robert Blank explains that: 'Rationality has come to mean the conscious, goal-oriented, reasoned process by which an individual, expressing and thus also revealing his or her preferences, chooses a utility-maximizing action from among an array of alternative actions.'[99] However, it is also possible to consider free will as a concept whereby at the moment that a decision is made, given everything that has happened in the past, it is possible to reach a different decision. Some commentators even believe a nonphysical 'soul' is directing decisions.[100]

In light of these perspectives, developments in neurosciences have given weight to discussions relating to the existence of free will between two different groups: those who support a physical and mechanistic explanation (that persons can be compared to machines controlled by their brains) and those who believe that human beings cannot be reduced to material bodies.

As such, a number of different positions can be taken, which will now be examined.

Incompatibilists

Those who have an incompatibilist position believe that determinism (which accepts that all decisions are predetermined by the brain) is not compatible with free will. These include two further groups called Libertarians and Determinists.

Libertarians

Libertarians believe that free will exists and that determinism must therefore be false. Their basic position is that a person can only be free if he or she genuinely has the ability to do otherwise. Many who hold this position also believe that freedom underpins all social morality.

Determining whether this strong sense of a genuine ability to do otherwise cannot be reduced to chance is one of the main debates between Libertarians and other positions. Indeed, some supporters of Libertarianism maintain that a strong argument supporting indeterminism can be derived from quantum mechanics, including the unpredictability of the behaviour and location of subatomic particles. This, it is argued, demonstrates that at the most fundamental level, the universe cannot be seen as being determined.

However, the relevance of quantum mechanics to the free will debate can be questioned, since even if quantum-level events were demonstrated to have an effect on brain-level functions, this would not necessarily offer any endorsement of free will. This is because any appropriate understanding of the concept of free will cannot be reduced to just another way of understanding uncertainty.

Of course, many Libertarians recognise that other influences, such as mental disorders, can influence free will. They also note that the free will of a person may be influenced by his or her character, which was formed after many free-will decisions. This implies that the character of an individual may have become such that he or she is simply no longer able to freely choose certain courses of action and that it would first have to change for this individual to be able to make another decision.

Determinists

With Determinism, all mental processes are the consequence of neuronal activations. This can generally be defined as neuroessentialism, which reflects the notion that mental states, behaviour, notions of self, and personal identity can be reduced to neurobiology.[101]

In other words, decisions are the end result of neuronal processes that come together into the most likely stable state in the given conditions,[102] which are themselves generally constructed from numerous variables and influences, such as the environment of the person. These neuronal processes are also influenced by the particular functional architecture of the brain, which is different in all individuals.[103] Thus, according to Determinism, at the moment of having reached a decision, a person could not have decided otherwise. As a result, neither free will nor responsibilities actually exist.

If Determinism is accepted as the sole reason for a decision, it would have significant repercussions for any legal system, since it would question the very concept of responsibility and make sanctions for any inappropriate behaviour meaningless. Determinists are convinced that there must be a neuronal cause for any deviant behaviour, whatever its exact nature.

As a result, it is possible to argue that any individual who commits a serious crime is affected by an abnormal and even dysfunctional brain, even if this has not yet been scientifically demonstrated. For example, genetic predispositions or other biological variables may have affected the construction of the networks associated with moral behaviour or may have led to weak control mechanisms for the inhibition of certain actions. In addition, these neuronal dysfunctions may have been caused by environmental conditions, such as an insufficient moral education or deficiencies resulting from a lack of training during brain development. It is also suggested that a brain's normal dynamics could have been affected by metabolic disturbances.[104] This all means that when a person decides to commit a crime, this may just have been the result of the activation state of the brain immediately before the decision was made.

Interestingly, Determinism is a position supported by many scientists, including neuroscientists Francis Crick (1916–2004), the British Nobel Prize winner and co-discoverer of the structure of DNA, who famously stated:

> The Astonishing Hypothesis is that 'You', your joys and your sorrows, your memories and your ambitions, your sense of identity and free will, are in fact no more than the behaviour of a vast assembly of nerve cells and their associated molecules. As Lewis Carroll's Alice might have phrased it: 'You're nothing but a pack of neurons.'[105]

It has even been claimed that the very belief in free will is responsible for much of the world's misery and is quite immoral.[106]Interestingly, however, researchers have demonstrated that when people do not believe in free will, they are more inclined to act in antisocial manners. They even found that their disbelief was associated with lenient attitudes towards cheating among tested students. As a result, the study suggested that the public should be encouraged to believe in free will, since, whether or not it actually exists, people seem to act more morally if they believe in it.[107]

Compatibilism

Another position in the free will debate is that of Compatibilism, whereby free will is compatible with Determinism. This position was supported by medieval scholars, such as the Italian St. Thomas Aquinas (1225–74), and by more modern individuals who investigated free will, such as the British philosophers David Hume (1711–76) and Thomas Hobbes (1588–1679). However, there is much discussion about the manner in which free will can be compatible with Determinism, and a number of theories exist that will not be examined in this study.

At this stage, it is also important to emphasise how the concept of predictability can exist alongside both Determinism and free will. Of course, if neuroscience can demonstrate that a human brain can be completely explained mechanistically, then it would, theoretically, be possible to completely predict what will happen. But the concept of predictability may also be compatible with free will if, for instance, it is possible to predict which choice a person will make, even though he or she retains a genuine freedom to do otherwise.

The concepts of predictability and free will are indeed quite different in nature. This implies that being able to predict a certain decision in a person does not mean that he or she is not responsible for this decision.

State of the Current Debate

A number of scientific results have been used to make the claim that free will may be an illusion. This included a series of experiments performed by the American scientist Benjamin Libet (1916–2007), in which individuals were asked to indicate, as exactly as they could, the moment when they were first aware of their intention to initiate a movement action.[108] At the same time, the researchers examined the moment when the brain actually started to prepare the movement (the so-called 'readiness potential') measured by EEG.[109] The experiment demonstrated that the occurrence of the readiness potential preceded conscious awareness of the intention to move by up to half a second. In another similar experiment, scientists were able to use fMRI to predict simple decisions made by research participants up to 11 seconds before they seemed aware of their decisions.[110]

In these investigations, the research participants appeared to be unaware that their behaviour was the result of automatic, unconscious processes that were controlling their actions.[111] Other researchers have described a whole range of situations, from facilitated communication to automatic writing, where persons believe they are not the authors of actions they have initiated and controlled.[112]

Though these results have been reproduced and confirmed, the discussion as to what they actually mean remains open. Some contend that they provide strong evidence that individuals do not consciously initiate actions and that a person's sense of conscious deliberation, agency and autonomous decision-making is illusory.[113]

Then again, others believe that the research results may in fact be more complex, since the experiments are very simplistic in nature. While there is no reason to question that the brain may begin to prepare a person for action, this does not mean that a person does not have an ability for conscious deliberation and action that builds upon his or her sub-intentional acts.[114]

Libet himself did not believe that these findings demonstrated that free will did not exist; instead, he argued that a person's ability to make free decisions rested on his or her ability to exercise a conscious veto on any unconsciously generated action – a so-called 'free won't'. If the 'free-won't' veto existed, it would give the conscious self the final say in whether an unconsciously generated decision is acted upon.

The Inexplicable Nature of Free Will

Although neuroscience has made great progress during the last century in terms of understanding the human brain, its contribution to explaining the human mind remains limited. The minds of human persons transcend their brains or bodies and it is therefore impossible to reduce these minds to a purely scientific perspective. This means that free will may not be something that can be reduced to neurobiology.

Albert Einstein (1879–1955), the German-American Nobel Prize winner in Physics, wrote in 1933:

> Honestly, I cannot understand what people mean when they talk about the freedom of the human will. I have a feeling, for instance, that I will something or other; but what relation this has with freedom I cannot understand at all. I feel that I will to light my pipe and I do it; but how can I connect this up with the idea of freedom? What is behind the act of willing to light the pipe? Another act of willing?[115]

For Einstein and many other scientists who endorse this view, there seems to be a difficulty in understanding the distinction between the physical manifestation of human thoughts, beliefs and ideas in the brain, and the manner in which the thoughts, beliefs and ideas come to exist. They fail to accept that a difference in kind exists between the brain and the mind, and that any attempt to completely explain mental experiences solely in physical terms is doomed to failure.

Though humans are psychosomatic unities, in which the brain and the mind are united, this does not mean that the mind can be reduced to biology; indeed, these aspects of the human being are all interdependent and mutually irreducible.

Of course, human beings become aware that they are persons by means of the body, which, in a way, reveals the person. Moreover, many influences, both biological and environmental, will always have direct or indirect effects on the mental state, and consequently on the free will, of a person. Even concepts such as sentimental love are likely to have a strong biological basis. But free will cannot be reduced to biology, the social environment of a person or the effects of direct neuronal interfaces if these become more developed in the future. Generally, a conscious person will always be aware when he or she retains free will or when he or she is being coerced, whether in real or virtual reality. As the American neurologist William Cheshire explains:

> A brain-based neuroethics ultimately is a paper ethics, a morally thin construction that tears under the stress and collapses under pressure. A genuinely human neuroethics, by contrast, rises beyond its stature and reflects a wisdom not entirely its own.[116]

In legal and moral matters, total and complete freedom to make a free will decision may not exist, since all actions are conditioned to some degree by both biology and the environment. But at the same time, a completely material cause of free will cannot be accepted if the capacity of an individual to self-transcend exists. Moreover, juries or judges in court trials are usually very capable of distinguishing between degrees of responsibility arising from free will decisions.

In this regard, it is interesting to note how troubled and offended human persons often become when they are compared to zombies, biological robots or puppets. This is noteworthy because it emphasises how much human beings seek value in being able to make free will decisions without being determined by, or reduced to, factors such as neurobiology or computers. Free will defines them for who they are. It gives them purpose, meaning and hope. This is because if free will did not exist, any moral edifice would collapse, since trust, sacrificial love and many other concepts that make human life worthwhile would become irrelevant.

At the same time, it is recognised that a better understanding of free will is certain to arise from scientific advances in neurobiology, which will also help clarify the philosophical and ethical debates regarding freedom, autonomy and moral responsibility. Research may also eventually address behavioural burdens resulting from some brain dysfunctions.[117] But the characterisation of human persons and their responsibility in this world confers on them a value and dignity that cannot simply be reduced to biology. Even though humans are physical beings, they cannot be explained by mere scientific concepts, since they can transcend the concept of physicality. According to this view, self-awareness and consciousness are mysteries that scientists and philosophers will never be able to fully understand and are, in this regard, similar to the concept of free will. In fact, consciousness is related to free will, in that it is conscious reflection and deliberation that enables a decision to be made between alternatives, thereby generating moral responsibility.[118]

But the fact that consciousness and free will remain a mystery does not mean that these concepts do not exist or that they are unimportant. As such, the very notion that individuals have a capacity to make free decisions, without being unduly influenced by deterministic factors beyond their control, is central to the concept of ethics in a civilised society and of democracy. This accepts that citizens have responsibilities and the capacity to make free decisions without being unduly influenced by any external and internal constraints. For example, without such an assumption, voting in democratic elections would become meaningless.[119]

Moral Enhancement

It has long been acknowledged that the behaviour and even the frame of mind of an individual can be modified through neurological interventions.[120] Because of this, some ethicists, such as Julian Savulescu and the Swedish philosopher Ingmar Persson, have suggested that it may be possible in the future to consider moral enhancements that would enable a person to better decide what is right as opposed to what is wrong.[121] This way of thinking has its origins in Greek philosophy, with Plato writing: 'For no man is voluntarily bad; but the bad become bad by reason of an ill disposition of the body and bad education, things which are hateful to every man and happen to him against his will.'[122]

In this regard, the Swiss-American bioethicist Fabrice Jotterand explains that moral discernment includes:

– a moral capacity that can be defined as an 'ability or disposition to respond morally and involves the motivational, cognitive, and affective mental process determining how one behaves when confronted with moral dilemmas'; and
– a moral content that can be characterised as 'the set of particular beliefs, values, and ideas shaped by environmental, cultural, and historical factors in addition to rational and moral deliberation and moral theorizing'.[123]

In other words, moral discernment reflects questions about the role of reasoning in moral deliberation, including how this is grounded on the neurobiological as well as psychological makeup of the person and the manner in which what is believed to be good, right and just is defined from a rational perspective.[124]

For some, moral enhancement seeks to improve moral capacity such as empathy, solidarity, justice, shame, and forgiveness. For others, however, such an enhancement would just seek to address moral dysfunctions such as psychopathy.[125] But whatever the understanding of moral enhancement, it may generally be seen as an attractive proposal, since morality is often considered as being desirable and something to which individuals and society should aspire. This means that if it is possible for neuroscientists to identify parts of the brain that seem to be associated with moral decision-making, it may then be an attractive proposition to consider morality as something that can be identified and improved through technology.[126] In this respect, it may be appealing to see how moral enhancement may be influenced by direct neuronal interfaces; in other words, how it may be possible for such technology to help make a person 'a better person' by enhancing their moral thinking, behaviour and decision-making, while remembering that that any discussion about morality cannot take place without a conception of what is considered rational and good in a specific social environment.

However, there may be some significant difficulties with such a proposal. In the first place, moral enhancement cannot simply be reduced to applying constraints to control behaviour because having a genuine moral character is not associated with the use of enhancement technologies that result in particular outcomes. This means that enhancing morality cannot merely mean the use of interventions in the brain.[127]

In the future, some governments may even consider the possibility of 'social enhancement', which can be defined as the use of biomedical technologies for the common good of societies.[128] Indeed, it has already been suggested that by using neurofeedback or deep brain stimulation (DBS), there may be a possibility of making certain people more empathic, which opens up possibilities for the rehabilitation of certain criminals.[129] But this could also be seen as being closer to a form of authoritarian control by the state than a way of making a person more moral in character.

Second, those who understand the concepts of virtue, insight and sympathy, as well as empathy, and who may know what is right and good are not necessarily the same persons who decide to do good – for example, they may have a weak will.

The difference between knowing the good and doing the good is entirely dependent on free will. Without free will, good cannot be a choice and virtue becomes meaningless.[130] But if a person makes it impossible for himself or herself to do what is considered to be bad, questions may then be asked as to whether this can even be seen as a form of moral enhancement; instead, it could just be compared to some kind of mental prison.

This means that caution is necessary with respect to any claims for moral enhancement. In other words, it is very unlikely that a better understanding of the biological foundation of human behaviour may enable applications to the brain that may significantly improve the morality of a person.[131]

Free Will, Moral Responsibility and Cyberspace

If a fusion of the human mind of persons with cyberspace is made possible through the development of neuronal interfaces, this may eventually affect their free will and the way in which they are considered to be responsible.

In this respect, the influence of cyberspace on decision-making is already being reported, including with some websites encouraging persons to commit suicide or participate in fundamentalist warfare. Even computer games may restrict the choices of a person if they follow the rules of engagement (or the rules of the game). Because of this, individuals may become more susceptible to being controlled by others or computer programmes.

At the same time, it should be noted that the mind, including the free will of a person, can be influenced by a number of factors and experiences. Any increase in information, knowledge of language, geography, history, current affairs, science and medicine inevitably changes a person's mind and his or her attitudes.

In addition, it is recognised that a person's level of moral behaviour can be changed through experiences such as torture, alcohol, drugs and electroconvulsive therapy but also with positive constraints. For instance, children are capable of improving their mental faculties through external sources, such as educational activities, which are considered as being positive. The use of certain kinds of computer programmes could, in this regard, have a comparable effect to education.

Thus, it is likely that a direct interface between a computer and the brain of a person will, similarly, have both negative and positive effects. For example, a direct interaction between a human mind and cyberspace may enhance a person's imagination, though a computer program may be unable to create imagination as such.

Furthermore, some individuals may be tempted to use the virtual world because it may actually provide a degree of anonymity that may shield them from any unfortunate consequences. This implies that, in order to control a person's moral behaviour, it may be necessary to protect him or her from certain kinds of information, such as preventing children from accessing pornography.

Undoubtedly, however, the enhanced mind should help a person see things more clearly and weigh up alternatives with more reason. This means that having more information at one's disposal may enable a person to make better decisions, but it does not make a person more moral. Having access to more information can only help reflection on moral issues, since emotions and passions, for example, could still colour decisions. This means that enhancing the mental functions of a person through the use of neuronal interfaces would not automatically make a person more moral, though it may make him or her more informed and responsible for his or her acts. It would also partly depend on whoever or whatever is feeding the information through the neuronal interface. Caution is therefore required.[132]

In this regard, freedom of thought, conscience and religion is considered to be very important in a civilised society. This is why the Council of Europe

Convention for the Protection of Human Rights and Fundamental Freedoms seeks to protect such freedoms by indicating in Article 9 that:

> 1. Everyone has the right to freedom of thought, conscience and religion; this right includes freedom to change his religion or belief and freedom, either alone or in community with others and in public or private, to manifest his religion or belief, in worship, teaching, practice and observance.
> 2. Freedom to manifest one's religion or beliefs shall be subject only to such limitations as are prescribed by law and are necessary in a democratic society in the interests of public safety, for the protection of public order, health or morals, or for the protection of the rights and freedoms of others.

This means that respect for human dignity and the integrity of the person implies an ethical prohibition on coerced alteration of the brain that could have adverse consequences on the flourishing of the person.

In other words, there is a right to freedom of thought and conscience in the face of persuasive and cognitive-altering technologies, such as those already in existence with subliminal advertising and certain other neuronal interfaces.[133]

Changing Consciousness

Being aware of something is the state or quality called consciousness. It may be defined as the control system of the mind to which is attributed subjectivity, awareness, sentience, feeling, wakefulness and the sense of selfhood. As Cheshire explains:

> Human self-consciousness includes the cognitive capacity for personal agency or the awareness of oneself as intentionally generating an action, as well as the sense of ownership over one's decisions and behaviors.[134]

However, what consciousness actually is has presented a challenge to philosophers over the centuries. *The Blackwell Companion to Consciousness* indicates that consciousness is: 'Anything that we are aware of at a given moment forms part of our consciousness, making conscious experience at once the most familiar and most mysterious aspect of our lives.'[135] But a number of senior neuroscientists suggested that it may be too early to propose a definition. They explained in a 2004 book entitled *Human Brain Function*:

> We have no idea how consciousness emerges from the physical activity of the brain and we do not know whether consciousness can emerge from non-biological systems, such as computers . . . At this point the reader will expect to

> find a careful and precise definition of consciousness. You will be disappointed. Consciousness has not yet become a scientific term that can be defined in this way. Currently we all use the term consciousness in many different and often ambiguous ways. Precise definitions of different aspects of consciousness will emerge . . . but to make precise definitions at this stage is premature.[136]

This follows what the British psychologist Stuart Sutherland (1927–98) wrote in 1989 in the *Macmillan Dictionary of Psychology*:

> Consciousness – The having of perceptions, thoughts, and feelings; awareness. The term is impossible to define except in terms that are unintelligible without a grasp of what consciousness means. Many fall into the trap of equating consciousness with self-consciousness – to be conscious it is only necessary to be aware of the external world. Consciousness is a fascinating but elusive phenomenon: it is impossible to specify what it is, what it does, or why it has evolved. Nothing worth reading has been written on it.[137]

However, philosophers have tried to understand some of the properties related to consciousness by asking the following questions:

- Does consciousness really exist?
- Can it be explained mechanistically?
- Is there such a thing as nonhuman consciousness and how can it be recognised?
- What is the relationship between consciousness and language?
- Can consciousness be understood other than in the dualistic distinction between mental and physical states or properties?
- Will computers and robots ever be conscious in the same way as humans?
- Is consciousness an all-or-nothing concept? In other words, as soon as an individual is conscious of others or of self, is it difficult to be more or less conscious of others or of self?

Many scholars also accept that consciousness is relational in some way and is dependent on interactions or communications;[138] in other words, it is associated with aspects that are self-relational and/or other person relational. In 1998, the British neurobiologist Steven Rose indicated that:

> My own view, however, is that the issue of consciousness lies beyond mere neuroscience, or even psychology and philosophy. The point about brains is that they are open, not closed, systems, in continued interaction with their environments. And for humans, that environment is both the immediate present constituted by the society in which we are embedded, and the past, expressed in our individual and social histories. Consciousness is fundamentally a social phenomenon, not the property of an individual brain or mind.[139]

In this context, and even though some scientists view the concept of consciousness with scepticism, it has recently become a research subject in psychology and neuroscience where biological, neuronal and psychological aspects of consciousness are investigated. These studies examine consciousness by asking people to report on their experiences such as: 'Did you notice anything when I did that?' They highlight aspects of subliminal perception, blind-sight, denial of impairment, the effects of psychoactive drugs and spiritual or meditative techniques.

Consciousness is further studied in medicine by examining a patient's response to stimuli according to a scale encompassing full alertness and comprehension to disorientation, delirium, loss of movement and loss of meaningful communication.[140] But practical issues arise when considering the consciousness of severely ill, comatose or even anesthetised patients, as well as the manner in which conditions associated with impaired consciousness should be treated.[141]

In this regard, a number of characteristics have been proposed as being necessary for the concept of consciousness to be experienced in a person, namely:

– A state of awareness of being awake: a person needs to be aroused, alert or vigilant and needs to be aware that he or she exists.
– Experience and attention: a person needs to be able to experience one moment leading to another.
– Having a sense of volition supported by a mind: this includes free will, beliefs, fears, hopes, intentions, expectations and desires.[142]

Neuroscientists have also investigated the perceptions inside the brain of the conscious individual. In this way, Greenfield suggested that an appropriate theory of the way in which physical brains may trigger certain subjective experiences would need to include the following questions:

– Can the theory describe how consciousness relates to the body as the boundary of self? In other words, if consciousness is generated in the brain, a credible theory should be able to account for the way in which individuals experience their bodies as the boundaries of themselves. This is important in a far more networked society where the dangers of feeling part of a greater collective, which breaches the limits of a person's sense of individuality, may exist.[143]
– Can the theory explain how different neuronal applications, such as drugs, may produce different states of consciousness?[144]
– How can the theory be verified? As yet, there are no objective ways of assessing the transcendent component of consciousness. Indeed, it is very

> difficult to verify theories about how consciousness emerges from the brain of a person, since only this individual is aware of such an experience.[145]

Because of this, it is very likely that conscious beings will never be able to fully understand consciousness.[146] Maybe a greater or deeper consciousness will lead to a better understanding of the concept, but perhaps human beings are actually limited by their own consciousness in understanding consciousness.

This enigmatic aspect of the concept is also related to its very existence, something that the English evolutionary biologist Richard Dawkins noted in his 1976 book *The Selfish Gene* when he wrote: 'The evolution of the capacity to simulate seems to have culminated in subjective consciousness. Why this should have happened is, to me, the most profound mystery facing modern biology.'[147]

Interestingly, it is easier to determine the lack of consciousness than to understand its presence. Moreover, since it is already possible to reduce consciousness, an increase in consciousness may well become feasible. For example, in the same way as some amphetamines and other psychotropic medicines can enhance awareness and awaken the brain, it may be possible in the future to enhance the consciousness of a person through a direct interface with cyberspace. In this regard, Greenfield writes:

> We can, then, think of consciousness as a phenomenon that deepens or lightens, expands or contracts, is more or less from one moment to the next; it would be a phenomenon that is essentially variable and ranging in quantity from the here and now, the 'booming, buzzing confusion' of an infant or the flimsiness of a dream or a drunken moment to the deep self-consciousness of introspection of the adult human. We could then see how such ever-changing levels of consciousness match up with an appropriately changing landscape in the brain. But what might the something be, that we could measure, that was ever changing in the brain?[148]

In short, many questions remain unanswered with respect to the concept of consciousness and some may even be unanswerable.

Primacy of the Mind over the Body

Interestingly, some individuals (including many young people) already seem to be so absorbed by their laptops, with their earphones in both ears, that only their bodies appear to be present. In a way, their minds are so far away in cyberspace that it becomes difficult to communicate with them in any traditional manner, such as using gestures or speech. Therefore, a kind of dissociation may be taking place between the mind and the body (a form of dualism), with the mind being seen as far more superior, in its capabilities, to the body.

This partly resonates with some of the ancient beliefs, such as Manichaeism, which were present in Europe between the third and sixth centuries. It taught an elaborate dualistic worldview in which a struggle existed between a good, spiritual world of light and an evil, material world of darkness, with salvation representing an escape from the body.

These beliefs were themselves based on Mesopotamian Gnosticism, which held that the world of the Demiurge is the lower, imperfect and ephemeral world associated with matter and time. On the other hand, the world of God is the upper eternal world, which is not part of the physical world, and is instead associated with the soul and with perfection. To reach this world, the Gnostic had to find the 'knowledge', from the Greek *gnose*, which is a mix of philosophy, metaphysics, curiosity, culture, and knowledge, as well as the secrets of history and the universe.

Network Consciousness

In a similar manner to what has already been considered when examining the concept of network intelligence, it may be possible to contemplate the concept of network consciousness or hive mind in the context of neuronal interfaces. In this manner, it may be useful to examine the possibility of bringing together a number of minds in cyberspace and how this may significantly affect the very concept of individual consciousness. A network of consciousness may then come into existence, which may transform itself into a super meta-consciousness. However, this will be further examined in a later section.

Escaping Reality

Reality is the state of things as they genuinely are rather than as they appear to be, are imagined or are theorised. It is the actual circumstances and the truth of humanity's existence. But at the same time, Hobbes famously argued that the real life of a human person was a significant challenge, being 'solitary, poor, nasty, brutish and short'.[149] As a result, seeking to escape such a physical reality, with its associated suffering, has always been attractive to humankind since the dawn of history. The reduction of suffering is still one of the greatest aims of modern society.

In the 1993 book *The Giver* written by the American author Lois Lowry, the story is told of a society where suffering no longer exists and where everyone is always content. However, when a young man, named Jonas, becomes an adult, he is chosen to be the community's 'Receiver of Memories' and enters into training with an elderly man called the 'Giver'. Through this Giver, Jonas learns about pain, sadness, war and all the unhappy truths of the 'real' world. But he also begins to understand that his community is a sham and extremely shallow in its understanding of the values of life. The book goes on to explain that having at least some capacity to suffer is necessary for a person to experience genuine compassion and friendships. This is interesting, since it can be argued that true happiness may simply be a byproduct of other things, such as work, discipline, sacrifice – even pain – and cannot be a goal in itself. The English philosopher John Stuart Mill (1806–73) noted: 'Ask yourself whether you are happy, and you cease to be so.'[150]

Escaping Reality in Cyberspace

One of the first times that the possibility of completely escaping reality was considered was when the American philosopher Robert Nozick (1938–2002) presented a thought experiment of the 'Experience Machine' discussed in his 1974 book *Anarchy, State, and Utopia*. In this, an individual would be floating in a tank while neuropsychologists stimulate, through the use of electrodes attached to his or her brain, wonderfully pleasurable experiences. Nozick then discusses whether individuals should choose such an existence of pleasure, happiness and bliss instead of living in reality. He asks what else would matter to a person apart from what he or she experiences 'from the inside'.[151]

The possibility of making such a decision is also presented in the already mentioned 1999 Film *The Matrix*, when the main character, Neo, is given the choice between two different pills. The blue pill would allow him to remain in the fabricated imaginary cyberworld of the Matrix, thereby living the illusion of an imaginary but easy existence, while the red pill would enable him to escape from the Matrix and into the real world, thereby living the harsh truth of reality. Interestingly, Neo eventually decides to take the red pill, even though he is aware that this will make life a lot more difficult.

However, the need to escape reality for a while may be considered a good thing when it becomes harsh or difficult. It may enable 'survival' or increase coping strategies. This may happen through different means, such as with a good fiction book, film and comedy. Rest from duties can also allow a person to sit back and contemplate his or her reality or enable dreams to be formulated based on difficulties and unmet needs. Indeed, it is possible to suggest that some fictional stories may help individuals address, process and think through real reality.

In this regard, entering into a virtual world can be seen as a kind of recreational experience. It may also enable a person to become an idealised extension of his or her own being, experiencing a new kind of freedom and even power that he or she would not otherwise have. For example, cyberspace computer games give players the possibility to do new things – even extraordinary things – that they would not otherwise be able to do in real ordinary life.[152]

This was reflected, for instance, in the 2011 science-fiction novel *Ready Player One*,[153] written by the American author Ernest Cline and made into a film of the same name by Steven Spielberg in 2018, which presents a society in which the principal aim of many people is to escape the real world. The story is set in the 2040s, where an overpopulation, energy and global warming crisis has given rise to significant poverty. In the midst of this harsh real world, many people seek refuge in the virtual and far more attractive world of the OASIS, a setting that is made even more real through the use of visors and haptic technology, which re-creates the sense of touch in the body of the user through the use of gloves and body suits.

However, the further individuals become immersed in the virtual world, the harder it may be for them to cope with the problems and challenges of real life. As a result, the desire to escape from the real world to a virtual one becomes increasingly stronger. Accepting present reality in a spirit of humility and service may seem more and more difficult.

Many people also have ambitions and aspirations, but find it difficult to implement these in real life. By escaping reality, they may be able to create their own world, which they can control. The adventure survival video game *No Man's Sky*, released in 2016, developed and published by the British studio Hello Games, involves bringing into being a new universe by enabling a person to quickly create planets and change things at the push of a few buttons.[154]

But such cybergames are still based on aspects of reality, enabling players to recognise the virtual environment. One of the ways in which this is done is by using the following three existential characteristics:

1. Defining the beginning and ending of an existence: birth and death delineate an individual's existence and without these attributes, it would be difficult to place a virtual existence.
2. Creating a context of time: this enables a sense of continuity between past, present and future – for example, future consequences are based on past events.
3. Enabling a sense of fragility and suffering: this reflects the finite and vulnerable aspects of life.[155]

If these three features are simply ignored or dismissed in virtual reality, it may eventually not represent any reality at all.[156] But merely replicating these reality features in cyberspace would only re-create a situation from which persons are seeking to escape. Thus, virtual reality seeks to support the creation of new, alternative and imaginative realities. The greatest benefit of virtual reality is that it suspends and improves the existential threats, concerns and constraints of real reality.[157] It then becomes a place where finite experiences are transformed into an infinite set of imaginative possibilities that a person can explore.

However, if the chain grounding virtual reality is broken from the basis of real reality, cyberspace could quickly become something far more threatening. This would happen if persons begin to reject the real world and seek to spend their whole existence in virtual reality. Instead of presenting a safe place in which exploration is made possible, it may become, as Brent Waters explains, 'a Gnostic and Manichean inferno whose inhabitants loathe the very existential features that anchor humans to the real world'. He adds that: 'It will be a state populated by cyborgs, who, in loathing the finitude and frailty of the body see it as rancid meat to be discarded.'[158]

Hopefully, such an experience can be avoided so that virtual reality may instead become a sanctuary in which it is possible to find a temporary release from the cares and limitations of the real world. But the best that virtual reality can offer is only a temporary rest from a world where difficulties are present. Any long-term or permanent existence in such a world would mean a life in which the heavy burdens of finitude and temporality would have no real meaning.[159]

Nevertheless, the wonders of cyberspace may tempt some individuals to become disillusioned with the real world, while others become so completely absorbed in virtual reality that they no longer pay attention to the real world, forgetting even to sleep, eat or drink. A previously mentioned example was the young South Korean man who died while constantly playing computer games for nearly fifty hours.[160] In such a context, it could be argued that, due to his vulnerability or obsessive-compulsive nature, his freedom had been taken away.

Moreover, seeking to always escape reality may be detrimental, in that reality is what human beings normally inhabit. It helps to define and shape them into who they are, while enabling them to be genuine. It offers the unexpected and the chance to grow and develop in ways that had never been imagined.

On the other hand, increasingly living in an imaginary reality may create difficulties for communities such as families. Indeed, existing in a pretend world may turn human beings into pretend persons. In this way, the development of avatars may represent an escape from the real self. Questions can then be asked about whether this is always right. Should individuals not instead learn to accept themselves as they really are and not live a lie?

There is responsibility, courage, nobility and even beauty in reality that enables individuals to become real persons confronting the real joys and hardships of real life. It is what gives real human beings real value. This means that, in some circumstances, the ethical appropriateness of escaping reality may be dependent on a number of factors and situations. For instance, the experiences of a person in the imaginary world may have a real impact on the real person. This can have both positive and negative aspects. If a person is violent in the imaginary world, this may enable him or her to calm down in the real world; however, the reverse may also be true.

Generally, any violence in the imaginary world may not have any real consequences with respect to responsibility in the real world. But it can also numb the sense of violence in the real world. The more the imaginary world seems real, the more dangerous this world may become. Maybe this is because individuals may no longer be able to discern between the imaginary and the real.

For a little boy to kill imaginary enemies may be inoffensive as long as the imaginary element of this game is quite strong – fictitious films, literature and video games can all be violent. But when real decisions are made (instead of being passive as in the cinema) relating to violent actions that seem very real, this could have a negative psychological impact on an individual. Indeed, the difference between 'active real' and 'active game' may become blurred for some individuals.

Research has confirmed that playing some violent video games is associated with changes in the behaviour of some users. The report by the 2015 American Psychological Association Task Force on Violent Media indicated that: 'The research demonstrates a consistent relation between violent video game use and increases in aggressive behaviour, aggressive cognitions and aggressive affect, and decreases in prosocial behavior, empathy and sensitivity to aggression.'[161]

However, there is insufficient evidence as to whether this then leads to criminal violence or delinquency. As the Task Force chair, the American psychologist Mark Appelbaum, explained: 'Scientists have investigated the use of violent video games for more than two decades but, to date, there is very limited research addressing whether violent video games cause people to commit acts of criminal violence.'[162]

The report suggested that playing such games may just be one of a number of factors involved in turning someone into an aggressive or violent person, stating that: 'No single risk factor consistently leads a person to act aggressively or violently.' Adding: 'Rather, it is the accumulation of risk factors that tends to lead to aggressive or violent behaviour. The research reviewed here demonstrates violent video game use is one such risk factor.'[163]

In this context, the effects on a player experiencing violent, imaginary and very realistic settings could be similar to those experienced by soldiers coming back from a combat zone in which they have seen real (and not imaginary) horrors. These soldiers are sometimes deeply disturbed and find it difficult to adjust afterwards. In the same way, a person may be deeply upset when awaking from a nightmare in which the setting seemed very real. But the opposite experience may also be true when an increasing number of soldiers live out the experience of war as if it were a virtual reality computer game. For example, through the use of drones, the seriousness and the horror of what is really happening may be taken away. In this case, reality may seem to become just a game.

One instance where this may have been encouraged was in the 2002 computer game *America's Army*. This was available as a free download provided by the U.S. Army in order to encourage young Americans to become new recruits. It enabled them to virtually explore Army life, including battle actions in which they killed the enemy. In the game, of course, the fighting and killing were only virtual, but the aim was to encourage would-be soldiers to do the same in reality with the U.S. Army. A further example of the risk of mixing virtual with real reality was reflected in the 2013 film *Ender's Game* directed by the South African Gavin Hood. In the film, young boys were trained in simulated war games with unforeseen consequences when the imaginary suddenly became reality.

In summary, a person seeking to escape reality with his or her imagination in cyberspace may end up in an easier or more fulfilled reality, but some caution is necessary when losing touch with reality. As with any adventure or experimentation, there may be risks where tools are used that are not fully understood or controlled, giving rise to dangerous unforeseen situations.

The manner in which the imaginary world is increasingly becoming similar to the real world may also create new challenges for some. Moreover, care should be taken when persons pretend that the real world is an imaginary world or the reverse. Few would deny the need for some leisure and rest; however, when the 'unreal' becomes just as real as the 'real' for a particular person, this may be cause for concern. Maybe virtual reality should be clearly delineated? Yet, once again, it is often difficult to separate reality from the imaginary in children and this does not generally result in any untoward or negative effects.

Changing Mood

Good health, it has been suggested, leads to happiness, but disorders can lead to sorrow. Given this, each of the basic emotional states (happiness, sadness, anger, fear and disgust) could be associated with consistent, identifiable and discernible patterns of brain activation.[164]

On this account, one the most-studied emotional states is depression because of its prevalence amongst the general public. When physicians seek to implement a treatment for a depressed patient, they do this not only as a result of their desire to help, but also because of the patient's expectation of receiving a tangible form of treatment. This may include a prescription for antidepressants, for which both the risks of known and unknown adverse effects must be balanced against the benefits. Medicines are often easier to use than counselling, behavioural therapy and getting rid of life's stressors or creating a more favourable environment in which to live. This means that rather than looking at the causes, medicine may sometimes look for a quick solution that may result in a dependence on the medical and pharmaceutical professions.

In this respect, 'mood enhancers' can represent a number of psychoactive drugs now available in medicinal and recreational contexts. They can enhance the mood in the sense of intensifying whatever emotions the user is experiencing or of improving the mood towards some 'more positive' state. But concerns already exist that human beings may eventually be reduced to being doped in a world of permanent euphoria and contentment.

This may imply that there is something inherently dishonest in seeking to always alleviate distress and negative emotions through artificial means, since, as already noted, human beings may need a capacity to suffer in order to be really themselves. Being unable to suffer would relegate persons to the state of happy robots who are unable to experience compassion in its truest sense. However, this argument is in many ways analogous to the claim that hard work is a virtue when enhancement could result in the same ends,[165] and is susceptible to the same criticisms.[166] Moreover, unease about the authenticity of an experience may no longer really matter if human beings find a way of permanently controlling their emotions and reacting to experiences.

With new developments in brain research, it is expected that more effective treatments of psychological or psychiatric disorders will eventually be developed. For instance, if it is possible to use brain-scan technology to locate and map stored memories in the brain, traumatic memories could then be removed and more pleasant ones enhanced or even created.

More generally, while still in its infancy, developments in neuronal interfaces seeking to manage a person's moods and wellbeing seem likely within the short to medium term.[167] When persons are clinically depressed, some are already being given therapy, such as electroconvulsive therapy (ECT), when this is considered appropriate. In other words, improving the moods or feelings of individuals could help in a healing process, provided it is done with their consent, is a short-term measure and is not manipulative. But it would be unacceptable to advocate antidepressants, or procedures such as ECT, for someone who was not clinically depressed because of the fear of causing inappropriate harm.[168]

Already, brain implants delivering electrical pulses regulated to a person's feelings and behaviour are being studied. Two research groups funded by the U.S. Defense Advanced Research Projects Agency have started to examine 'closed-loop' brain implants, which include: (1) the participant; (2) signal acquisition; (3) signal analysis; and (4) signal feedback. Such implants are also used in association with algorithms to identity mood disorder patterns that can decide when to stimulate the brain back to a normal state. At present, only individuals with epilepsy who already have electrodes implanted in their brains to address their seizures are being studied. Indeed, these implants can be used to record what happens when they are stimulated intermittently instead of permanently, as with other older implants.[169]

But one of the ethical concerns with artificially exciting certain parts of the brain associated with mood disorders is the possibility of also creating extreme happiness, which may overcome all other feelings. Another ethical consideration is that such procedures could enable certain persons to access, to some extent, an individual's inner mood and feelings, even if these remain hidden from visible behaviour or facial expressions.[170]

Thus, the ethical acceptability of using neuronal interfaces to address or improve a person's mood or feelings would depend on a number of factors, such as possible side-effects, the amount of time a person uses such a procedure, the consequences that it may have on others and the extent to which it alters a person's understanding of reality. The kind of applications being used would also need to be considered and whether they are invasive or noninvasive, since the person may become psychologically, rather than just physically, inseparable from a device.

Changing Personality

Evidence that changes to the brain can modify a person's personality or moral behaviour have been known about for some time, with a number of famous cases. One of the most notable being that of an American man, Phineas Gage, who was a railroad construction foreman. In 1848, while using an iron-tamping rod to pack explosive powder into a hole, the powder detonated, projecting the rod through Gage's left cheek, penetrating his brain and exiting through his skull. Remarkably, Gage survived this accident but became, according to certain accounts, a different person. As, Edward Williams, the American physician who treated Gage, indicated:

> He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires . . . His mind

> was radically changed, so decidedly that his friends and acquaintances said he was 'no longer Gage'.[171]

Although some accounts of Gage's life after 1848 were not always accurate,[172] his case became a widely used example of how changes to the brain could have effects on personality and moral behaviour.

Another famous case, which was described in 2003, is that of a forty-year-old married schoolteacher who slowly became obsessed with child pornography, started to solicit prostitutes and sought to molest his step-daughter. Eventually, his wife evicted him from the family home after discovering his sexual advances towards her daughter. He was then accused and found guilty of molesting children. However, just before he began his prison sentence, he was admitted to hospital for headaches and an uncontrollable sex drive. An MRI scan indicated that he had an egg-sized brain tumour in the frontal lobe, which is important in regulating judgement, social behaviour and self-control. The tumour had also affected the hypothalamus, which plays a role in controlling sexual impulses. Interestingly, when the tumour was removed, the inappropriate sexual drive vanished and the patient was able to behave normally. But after a number of months, the man secretly started to watch pornography again. Another MRI scan revealed that the tumour had regrown and was subsequently removed. As a result, the new inappropriate sexual drive disappeared once more.[173]

Intentional, though coarse, personality-altering technologies have also been in existence for some time, such as ECT, castration, psychoactive drugs and behavioural therapies. Even experiences of violence, containment and torture have been considered in seeking to change the behaviour traits of a person.

In the past, treatments of personality disorders were usually considered for persons with behavioural problems, such as 'irrational criminals' or sexual perpetrators, and – in the rationale of authoritarian and totalitarian political regimes – certain political dissidents (who were also seen a criminals, mentally ill or both).[174] An example of such procedures was presented by the English writer Anthony Burgess (1917–93) in his 1962 book *A Clockwork Orange*, in which a violent sexual attacker is subjected to a correction treatment in which he is forced to witness violent crimes in order to inhibit his violent tendencies.[175]

From a less fictional perspective, Deep Brain Stimulation (DBS) in patients suffering from neurological disorders, such as Parkinson's disease, has also been reported to sometimes have personality-altering effects that may be significant, immediate, surprising and dramatic,[176] but these appear to be reversible when the DBS equipment is turned off. On the other hand, for some patients affected by Parkinson's disease, the changes in personality resulting from the disease or drug treatment, themselves, have actually been seen to be reversed through the use of DBS.[177]

As such, this confirms the possibility of using neuronal interface technologies for dramatic nondisruptive personality-altering effects.[178] These may then raise some serious ethical dilemmas in terms of the way in which a person considers who he or she is.[179] As Cheshire explains:

> Technologies that stimulate, inhibit, or modulate highly personal brain functions might render assessments of personal authenticity less certain. The person under the influence of the technology might ask with good reason, which is the 'real me?' – how I perceive myself and am inclined to think and act when the switch is turned on, or when it is turned off?[180]

Similarly, in its 2007 report entitled *Boosting Your Brainpower: Ethical Aspects of Cognitive Enhancements*, the British Medical Association indicates: 'There is something startling and potentially worrying about interventions designed to alter the healthy brain which controls such facets of personality, individuality and our sense of self. If we tamper with it, is there a risk we may lose our sense of who we are.'[181] But the report then goes on to note that a person's sense of identity changes, naturally, throughout his or her life, with different aspects of this identity developing over time.[182]

Nevertheless, it is accepted that any changes of identity using neuronal interfaces should only be considered after careful ethical consideration and only when seeking to restore, but not artificially modify, the genuine personality of a person. Moreover, in the same way as plastic surgery may not always be a remedy to the image problem of a person, the creation of a 'plastic personality' through neuronal interfaces may not always be the best experience for a person who wants a genuine personality.

Finally, it worth noting that the way in which changes to the brain affect personality are complex and not well understood. This means that a too-simplistic, one-to-one connection between changes in certain brain areas and specific personality modifications should be avoided.[183]

Changing Identity

Dictionary definitions of 'identity' are sometimes related to the work of American developmental psychologist Erik Erikson (1902–94) in the 1950s, who coined the term 'identity crisis'.[184] His concept of 'ego identity' suggested that the interaction of a person's biological characteristics, psychology and cultural context shaped his or her identity.[185] Given this, an individual's identity can be defined as the characteristics that determine who a person is.

Personal identity, on the other hand, can describe the way in which individuals perceive attributes that they consider as being uniquely their own. These merge to form an experience of embodied self in contrast to external reality.

Erikson also highlighted the consistency of identity over time, so that in different times and places, a person continues to have an innate sense of being the same person, although changing circumstances can still cause a shift in the sense of identity.[186]

The concept of identity is now essential in a wide range of disciplines and a number of definitions have developed accordingly.[187] For example, the notion of identity has been explored from a sociocultural perspective, or with an emphasis on discovering self-identity, such as in the transition from adolescence to adulthood.[188]

Generally, however, it is accepted that a person may reflect several aspects of identity that can best be understood as socially constructed, complex, multifaceted and highly contextual, reflecting the following points:

– The way in which individuals perceive themselves and their place in society, together with how they are seen by others. In this way, human beings may have coexisting, multifaceted, overlapping identities, which may vary depending upon the context. For instance, the same individual may be a parent, a company employee or a sports athlete.
– The choices of an individual when he or she becomes, for example, a member of a social group.
– The inclusive nature of identity when a person belongs to groups such as a family, team or religious community. However, there may also be an 'exclusive' angle when a person is rejected by a particular group.[189]

A previously discussed example is the Deaf community, in which some families develop a certain identity because of a congenital inability to hear. Being Deaf may indeed form a key part of someone's identity, especially when such a condition manifests itself at a young age. Any attempt to 'resolve' the condition, as though it is inherently problematic, can undermine the experience of identity of a Deaf person who does not view his or her Deafness as a disorder. A number of individuals go so far as to stress that they may lose part of their identity if they are no longer part of this Deaf community.

In discussing the concept of identities, it is also important to first emphasise the different ways in which these can be distinguished. Though a degree of overlap may exist and there is no consensus in the literature, it is possible to differentiate between the following:[190]

– Numerical identity, which examines the number of persons who exist and whether they are distinct. For example, it considers whether the continuous sense of a living being remains one and the same being throughout his or her life trajectory in the three dimensions of space and over time. In this case, two perspectives are generally presented, namely:

- a biological perspective that reflects the continuous biological being remaining one and the same whole being over time as a biological entity in space, despite some qualitative changes, such as those arising from the replication and division of cells making up this being;[191]
- a psychological or biographical perspective that reflects the relationship a living being has to itself as remaining one and the same whole individual over time, despite some qualitative changes. This generally includes continuity of consciousness, experiential contents or the maintaining of psychological connections or capacities, such as memories.

These different perspectives can, of course, be examined separately or together, enabling the living being to be considered a psychosomatic unity.

– Qualitative identity, which examines similarities between the same individual in different settings or between distinct individuals. For example, two beings may be similar from a biological perspective, but may exist in different settings of space and/or time. In this way, identical twins are qualitatively but not numerically identical. Each twin exists in a different setting of the three dimensions of space, though they generally live at the same time.[192]

– Narrative identities, which are based on how individuals might describe or perceive themselves (or be described by others), comprising aspects of memories, experiences and details that define the question: 'Who am I?'[193] Narrative identities concern aspects of self-conception instead of persistence over time. This means that numerical identity could remain the same, despite significant changes in narrative identity.

– Social identities, which are generated through roles and relationships between people and the wider social as well as cultural contexts. These include family relationships, friendships, membership of communities and attachment to particular places.

Interestingly, from a philosophical perspective, because human beings are always changing over time and are not exactly the same at any two moments, questions can be asked as to whether some of the above identities remain the same. This is especially important if a person is put on trial for a crime that 'he' or 'she' committed many decades beforehand, since it is possible to ask whether the same person is still present. In response, it can be stressed that a person may consider himself or herself to be a whole person, in a continuous sense, since the beginning of his or her existence and until the present time.

Such questions relating to a person's identity demonstrate why ethical dilemmas resulting from the potential use of neuronal interfaces need to be carefully considered, since challenges may arise if an appliance significantly changes some of the different identities of the person.[194] Questions can then be asked as to who the real person actually is and whether he or she would still be free to be who he or she really is, both before or after the appliance is used. For instance, in certain cases, narrative identities may be changed by affecting a human being's self-conception, while in other situations, the numerical psychological identity may change, even though the biological identity may remain the same.

Yet, as already mentioned, to a certain extent, changing and reshaping the different aspects of the identity of a person is something that is continuously taking place in every person.

Identity and Autonomy

The identity of persons is usually recognised to be closely associated with their sense of autonomy, which reflects an ability to act for specific and understandable reasons rather than just following instructions given by others without reflection. This ability enables individuals to develop a sense of 'who they are' and be 'true to themselves', while also determining the way in which others may recognise these persons.

Many cultures place a high value on the sense of self and the ability to exercise autonomy because it enables the development of a meaningful identity, while allowing relationships with others that are generally seen as important to living a fulfilling human life.[195] This means that an adequate ethical framework must be sensitive to this identity arising from the autonomy of a person existing in the setting of an interdependence of individuals.[196]

Identity and the Human Brain

The human brain is central to any discussion of identity because it is often characterised as the organ enabling the person, as such, to be integrated as a whole and over time through his or her capacity to be self-aware, decide actions and pursue relationships with others.

Unfortunately, however, some brain dysfunctions may interfere with a person's ability to form and maintain a connected sense of self over time at the most fundamental level. For instance, when persons experiences serious permanent memory loss, this may, to a certain extent, have serious consequences on their sense of identity and who they are.[197]

As already mentioned, a person's memories play an important role in his or her psychological identity, even though it may not always be possible to understand the various ways in which this occurs. The mind does not recall past experiences simply on an objective basis, but constructs interpretive memories to make these events meaningful as they are associated with other relevant and similar experiences.

Thus, as the benefits of neuronal implants are considered, it is important to be clear about the potential effects on identity-formation.[198] This is because neuronal interfaces and virtual reality technologies may have a powerful influence on storytelling tools, while enabling an improved level of control over memory formation which are both crucial parts in forming identity.[199]

As such, if individual memories that are relevant to a person's self-recognition are removed, altered, added to or replaced, this will have a crucial impact on his or her identity.[200] This is an important factor when brain interventions may cause unintended alterations in the mental function of persons. Indeed, this may have an effect on the psychological continuity of the individuals and the way in which they experience themselves as persisting through time as the same persons.[201]

The bioethicists Marcello Ienca at the University of Basel and Roberto Andorno at the University of Zurich in Switzerland have thus suggested that a right to psychological continuity exists that should protect personal identity from unconscious and unconsented alteration by third parties through the use of invasive or noninvasive neurotechnology.[202]

But neuronal implants could also impact on identity in other ways. Even if prosthetic cortical implants were originally developed to restore aspects of sight to visually impaired individuals, they could eventually enable them to also access information directly from a computer. As a result, if they can only 'see' through a computer, this may have unforeseen and even disturbing consequences on the manner in which they perceive their identity and sense of self.[203]

Another way in which implants could have an effect on identity is the already mentioned Human Brain Project, supported by the European Union, which aims to bridge the boundary between a human and virtual or robotic surrogate bodies. Interestingly, this is very similar to what was represented in the 2009 American science-fiction film, *Surrogates*, directed by the American Jonathan Mostow. This was based on the 2005–6 comic book series of the same name in which human persons live out their lives, in the comfort of their own homes, by embodying humanoid remote-controlled robots.

Yet, in the future, it may also be possible for an existing human person to live his or her life through the lives of other human beings if they all use neuronal interfaces. In this way, an individual may be able to experience all the sensory, emotional and cerebral experiences of other individuals of both sexes in a very real and 'direct' manner. A person could thus plug himself or herself into the brains of other men or women having a sexual relationship and live the same pleasurable experiences, which could have huge implications for the sex industry. It may even be possible for a single person to experience, for the first time, both the male and female orgasms.

However, the use of such robotic, virtual or human surrogates may have very important consequences in relation to how a person may consider his or her own identity. Thus, neuronal interfaces should be carefully considered in terms of their impact on identity and the associated, anthropological, social, ethical and psychological questions that arise.

Online Identities

As already noted, many people now spend a substantial proportion of their waking lives online or interacting with the digital environment, and future generations may experience even less of real life than was the case before the advent of computers. In recent years, social networking has expanded to include professional networking sites and other forms of expressions such as blogging, Twitter, avatars, gaming, personal webpages or membership of various Internet discussion groups. Mobile technologies are playing a role in driving change, with new formats and applications (apps) being launched to run on smartphones. This may mean that the notion of computers being separate from people is changing, since many individuals now keep a personal networked computer, in the form of their smartphone, with them all the time.[204]

Online platforms are also being changed both radically and rapidly in a proliferation of communication technologies that can be described as a 'poly-media' environment.[205] Individuals now use different appliances simultaneously or to complement one another.[206] Identities across online support systems may be broadly similar or may shift in emphasis, such as from a professional to a social identity, and shift between media, such as text messaging versus face-to-face conversations via a webcam.

The poly-media environment also requires an individual's identity to perform different functions at different times in a digital networked world, such as when a person uses an online bank, makes purchases from an online retail website or participates in social media.[207]

It is difficult to speculate on the likely impact of growing hyperconnectivity on identity. People may find it harder to disconnect themselves or to maintain distinct identities in different situations. The increasingly networked state of many people's lives could blur the boundaries between online and offline identities, as well as between work and social identities. The advent of widespread mobile technology and email has also led to an increasing number of persons remaining connected to their work during the evenings, weekends and other leisure times. This blurring of identities through social and technological changes could have significant transformative consequences for future individuals in society.[208]

Yet, while it may not always be easy for individuals to have multiple identities all at the same time, it is possible that modern generations may develop coping mechanisms to address these challenges.

Creating New Identities Online

Cyberspace is part of the new culture and is developing at such a rapid rate that, in the same way that some may watch a TV series in order to experience a fictional world, others may now increasingly live in cyberspace.

In the early years of Internet usage, there were concerns that it could diminish 'real' identity and reduce face-to-face human socialisation, with online identities being seen as very different from those in the offline 'real' world.[209] But it was also noted that being online made it easier for people to explore new forms of identities, such as through the use of fantasy avatars, and to change or secure multiple identities with relative freedom.

As individuals have become accustomed to switching seamlessly between the Internet and the physical world, they have also begun using social media to pursue friendships, continue conversations and make arrangements in ways that dissolve the divide between online and offline.[210] In this manner, the Internet may not have produced new kinds of identities,[211] but may instead have demonstrated that identities are more complex, culturally contingent and contextual than was previously thought.[212] For example, if a person of a certain nationality and cultural identity in real life develops an avatar in cyberspace that has a completely different national and cultural identity, the whole notion of belonging to a certain national group may then be questioned. This undermining of nationality could even be seen as a positive development, especially in places where violent conflicts exist between cultural groups in the real world.

That cyberspace identities are increasingly important to individuals can also be reflected in the way in which persons brag about how many followers or 'likes' they have on the social media online service Facebook. Some individuals in modern society seem to need to be connected and show that they are connected. There is a kind of existential requirement to be in relationships ('I am connected therefore I am'). The British social commentators Ed Brooks and Pete Nicholas indicate that when being connected becomes a priority, '"connection" becomes all-important, "sharing" becomes essential, our life is reduced to our place in a global grid where "I am who I am connected to"'.[213] However, the use of Facebook can also be seen as very positive in the manner in which it can open up new contacts with other persons or organisations.

Creating Fake Identities

Sometimes, different identities may place conflicting demands on individuals that may be detrimental to their health or wellbeing and may cause them to act in ways that have implications for the wellbeing or safety of others. Certain individuals may even lose touch with reality and the responsibilities they have towards themselves and others.

One concern in this regard is the manner in which the Internet makes it possible for a person to create fake online identities,[214] though social media sites generally seek to stop any deliberate deception as part of their terms and conditions.[215] Facebook revealed in 2012 that it had 83 million fake accounts (8.7 per cent of the total), though the majority were considered to be duplicates or misclassified rather than 'undesirable' accounts (only 1.5 per cent of the total).[216]

Individuals may create fake accounts to protect themselves from unwanted intrusion, to divide their work and social lives, or because they are required to have a unique user name,[217] though fake identities can also be created in order to perpetrate a crime.[218] However, over the next few years, technologies including facial recognition and other means of tracking digital 'footprints' may reduce the potential for fake identities remaining undiscovered.[219]

An example of the way in which the Internet can influence a person's identity was demonstrated when a married couple from Central Bosnia was reported to have begun divorce procedures after they unknowingly chatted each other up on the Internet using fake names.[220] Apparently, Sana Klaric, twenty-seven, and her husband Adnan, thirty-two, poured their hearts out to each other online over their marriage troubles. Using the names 'Sweetie' and 'Prince of Joy' in an online chatroom, the pair thought they had found a soulmate with whom to spend the rest of their lives. But there was no happy ending after they turned up for a secret date and realised their mistake.

Now the pair is seeking to separate after accusing each other of unfaithfulness. Sana explained: 'I was suddenly in love. It was amazing, we seemed to be stuck in the same kind of miserable marriages. How right that turned out to be.' But when it dawned on her what had happened, she said: 'I felt so betrayed'. On the other hand, Adnan indicated: 'I still find it hard to believe that Sweetie, who wrote such wonderful things, is actually the same woman I married and who has not said a nice word to me for years.'

Reflecting a More Positive Identity

As already indicated, it may be possible for persons to create completely new identities through avatars in cyberspace or surrogate robots in real reality[221] in order to make themselves more acceptable or attractive. It has also enabled some individuals to reflect what they felt were their 'true' identities as never before.[222] For certain persons with various forms of disability,[223] such as autism and muscular dystrophy, being online or having an avatar was the first time, they believed they could be seen by others as 'normal' human beings. Similarly, some people who may feel shy, lonely or less attractive may discover that they can socialise more successfully and express themselves more freely online.[224]

The 2009 American science-fiction film *Avatar*, directed by the Canadian James Cameron, set in the mid twenty-second century on a distant moon, recounts the story of a disabled man who can remotely control, through his mind, the synthetic body of a native avatar, which he uses to interact with the real natives. Slowly, however, this man begins to prefer living through his avatar, which seems a lot more interesting and attractive to him than his 'real' world.

Creating new identities online therefore allows people to find out how they might act/react in different situations and settings, or they may want to escape and discover new prospects if they are trapped in a real harsh reality. However, they may then find that they prefer their new virtual lives.

Dominance of Certain Online Identities

In the 1969 book *To Live Again* written by the American author Robert Silverberg, an entire worldwide economy is developed around the buying and selling of 'souls' (personal lives that have been tape-recorded at six-month intervals). This allows rich consumers to bid against each other for the opportunity to upload into their minds the most recent recordings of archived personalities. But federal law prevents people from buying a 'personality recording' unless the owner has died; similarly, two or more buyers are not allowed to own a 'share' of the same persona.

Such stories are mirrored, in part, in the real experiences of persons suffering from psychosis, where one identity seems to dominate another. Individuals hear voices that are often deprecating and have a negative impact on their health and wellbeing. Similarly, if a number of identities were present together in virtual reality, it might be possible for a dominant identity to take precedence, which could have a very negative impact on the other identities. But again, this will be examined more in depth in the context of network consciousness or hive minds in a later section.

Blurring of Online and Offline Identities

Another ethical problem that could arise is that the distinction between online and offline identities could become blurred. This was considered in the 2013 science-fiction film *Her*, directed by the American Spike Jonze. It tells the story of Theodore, a lonely man in the final stages of his divorce, who eventually falls in love with his computer program, which is advertised as the world's first artificially intelligent operating system. But it is not just an operating system – it is a consciousness called Samantha. As they start spending time together, he grows increasingly closer to Samantha and eventually finds himself in love. This reflects the problem that if truth and reality are lost, concerns and confusions may then arise.

Thus, the online and offline identities of an individual may converge into one single identity in some activities and diverge in others. This may depend on whether some individuals would increasingly prefer to live through their avatars and whether there is a deliberate attempt to keep them separate.

One example of how the online and offline identities of an individual may converge is in the use of the Internet for sex, with reports from 2013 suggesting that about 14 per cent of all searches and 4 per cent of websites are devoted to sex.[225] Cybersex is also possible in which a virtual sex encounter may take place between two or more people, connected remotely via a computer network, who send each other sexually explicit messages and/or images describing sexual experiences. In this case, the online sexual imagery and events may have direct and worrying effects on real vulnerable persons.

Conflict between Online and Offline Identities

In the future, the take-up of social media is likely to increase even further and may enable people to express different aspects of their identities. Maintaining an online presence could become normalised to the point where refusing to participate in online media could appear unconventional and may result in exclusion. Moreover, individuals may increasingly find that their online identities are created or mediated by others. The persistence and availability of data on the Internet means that social and biographical identities may also increasingly be merged to a greater degree across social and professional spheres.

This means that as societies engage with emerging technologies, there is a need to consider the potential impact on malleable self-identities and ensure there are no unintended or unnecessary detrimental consequences. However, it is impossible to be certain whether the modification of the identities of persons through the availability of virtual realities is positive, negative or neutral. For example, neuronal interfaces may be useful if they help people engage in more outgoing and positive behaviours or take on more challenging roles. On the other hand, it may encourage antisocial or pathological behaviour, or result in increased affiliation with subversive elements.

The Concept of Humanity

Though it has always been very difficult to define what is so special about humanity in the context of anthropology, with new developments in technology this is becoming even more difficult. Elaine Graham observes that: 'New technologies have complicated the question of what it means to be human in a number of ways.'[226] This includes the reality that the clear boundaries of the *Homo sapiens* species are increasingly coming under pressure, with ever more uncertainty developing about the exact limits of humanity. Graham explains this hesitation about what it means to be human as 'a dissolution of the "ontological hygiene" by which for the past three hundred years Western culture has drawn the fault-line that separate humans, nature and machines'.[227]

However, as already noted, discussions have always taken place during the long history of anthropology and philosophy about what it means to be a human person. Even in Greek mythology, for example, a number of chimeric human-nonhuman interspecies monsters were considered, such as the Minotaur, who/which had the body of a man and the head of a bull. These were generally seen as being special, but also disturbing and sometimes needing to be destroyed. In fact, the Minotaur was eventually killed by the Athenian hero Theseus.

In other words, real threats of species disorder have often been seen as resulting from the very existence of individuals who bridge the boundaries of humanity. The sixteenth-century French surgeon Ambroise Paré (ca. 1510–90) actually considered such beings as monsters and as a clear indication of moral disorder.[228]

Even after the Enlightenment, and modernity's rationalistic discussion of humanity, monsters were still being considered as moral frontier-markers. Graham explains that genuine humanity may be delimited by considering the monstrous 'boundary-creatures' who/which may also 'feature as indicators of the limits of the normatively human'.[229] At the same time, she explains: 'The limits of morality, represented by the monster, indicated in an inverted form the qualities of reason and benevolence by which the quintessentially human could be recognised.'[230]

This means that if the very concept of humanity is ever being questioned, some reassurance could be obtained by recognising that genuine humanity is, at least, not monstrous. But as a result of such arguments, there is a risk that those who do not consider themselves as monsters may find value and reassurance in their humanity at the expense of those who do not neatly fit into certain categories. Graham argues that it is then all too easy for those whose physical attributes are different from the norm to be considered as deviants.[231]

At the same time, with an ever-growing number of individuals reflecting new forms of bodies or neuronal interfaces, the norm may change. It follows that what may have been considered as monstrous in the past may eventually be accepted as a new normal. Moreover, it is worth noting that there is always something mysterious about humanity that resists definitions and any scientific reductionism. Even in the U.K. Parliament and the European Parliament, for instance, no definition of humanity exists in law, though all legislation enacted in these parliaments is based on a certain understanding of what it is to be human.

Humanity, the Human Brain and the Human Mind

Ever since ancient times, it has generally been assumed that some spiritual element in the physical human body must exist that brought it into life. The organs, by themselves, did not make all that much sense, but blood did, and clearly a substantial amount was required for a person to remain alive. Thus, blood was considered to be the key to life in antiquity, though the 'breath of life' was also seen as important. For centuries, the point in time when a person stopped breathing and his or her heart stopped beating was seen as determining the time of death.

However, with an increasing understanding of genetics, new insights into existence and nature were offered. The quest for the human genome became a kind of search for the book of life. Genetics seemed to explain why humanity was so unique and, as such, was seen to be useful in defining human beings. But this had its own problems once it was realised that about 50 per cent of human genes were found in bananas and more than 98 per cent were shared with chimpanzees. It was only when science moved from examining genetics to the brain, at the beginning of the twenty-first century, that a new emphasis became possible. This then discussed the nature of humanity as being associated with neurology and, more particularly, with the cerebral cortex – the part of the brain giving rise to thoughts.

Interestingly, this 'corticalistic' view of humanity reflects, in some way, the seventeenth-century idea of a small intelligent being, a homunculus, locked inside the biological brain-machine. Of course, the existence of such a being has now been dismissed, but questions about how a network of connected neurons can create consciousness, thoughts, intelligence, desires and other similar concepts remain intractable.

Within this context, one suggested path used to explain these abilities reflects the idea of emergence. This begins by observing that once a simple brain exists, such as the neurons in a worm, it can perform basic functions, but when a more complex brain, such as that of a bird, is considered, it can begin to conceive basic tools, while also adapting to different settings. If brain complexity is further developed, it is proposed that entirely new phenomena may emerge. It is thus implied that the human brain has evolved to such an extent of complexity that it has emergent personality.

However, this focus on self-awareness and thoughts, as the very basis for defining human beings, may signify that a machine operating with similar thoughts could be considered as having the same worth and value as a human being. From this perspective, the only requirement to create an artificial person is a computer with an appropriate processor capability, plenty of memory and a well-written program. The human body could then become redundant. In fact, the machine could also become redundant in terms of defining who this techno-person is, because it may eventually be possible to transfer the data and code to another machine and carry on as if nothing had occurred. Such a concept is interesting because, in a way, it introduces a new form of dualism whereby the person can be considered as data and code running in a physical machine. Yet, most people recognise that the idea that human beings are just thoughts and memories, with the body being seen as unimportant, is less than satisfactory.

Human Dignity

Though the notion of human dignity is complex, it generally describes elements of worth, value and respect recognised in, and by, others. For example, Article 1 of the EU Charter of Fundamental Rights, which was solemnly proclaimed in 2000, not only states that 'Human dignity is inviolable', but also that 'it must be respected and protected'.[232]

This implies that inherent human dignity is an international cross-cultural concept that binds all humanity together, while giving human beings a fundamental and universal value. However, it is important to clarify the meaning behind the word 'dignity' in such a document. Indeed, it can be used to emphasise respect for a person's autonomy and rights, but also to inhibit the choices of some in order to protect the dignity of others. Authorities are therefore required to provide an environment where the dignity of all its citizens can be recognised and respected.[233]

As such, inherent human dignity is usually considered as the basis for the rule of law in a civilised society. It is for this reason that it needs to be upheld and defended. Indeed, it was because of the concept of dignity that a decision was taken by a German court in 2004 to stop the commercialisation of laser guns used for 'killing' games by a company called Omega. This decision was considered lawful because games that simulated the killing of human persons for commercial purposes infringed human dignity – a fundamental value to the national German constitution.[234]

With respect to neuronal interfaces, a number of questions may be asked as to their possible effect on human dignity. It is even possible to ask how far neuronal interfaces can be used before some aspects of human dignity are undermined. This means that such interfaces may challenge previous notions of human nature and how many human functions can be substituted or even enhanced by technical devices before aspects of humanity are lost.[235] But since no definition of a human being exists, it will always be difficult to decide at what point a partially human cyborg may not be a human being.

However, what is certain is that devices that enforce unnoticeable personality alteration on human persons without their consent are a threat to their human dignity.[236] Furthermore, if such appliances could contribute to the creation of a network of persons who are always connected to each other while being controlled by others, this would be little different to slavery.

On the other hand, the human dignity of a person could perhaps be strengthened through his or her ability to connect with many others around the world. Such relationships may then encourage human beings, of all origins, to come closer together by emphasising their shared humanity over any differences of nationality or accidents of geography.[237] Thus, not all forms of neuronal interfaces should be seen as undermining dignity.

The Human Body: The Human Hard Drive

Generally, the way in which society considers and understands the human body helps to shape its understanding of new technologies and their applications. In this regard, the French physician and philosopher Julien Offray de La Mettrie (1709–51), who was one of the first French materialists of the Enlightenment, suggested in his seminal work *L'Homme Machine* that not only do human beings exhibit more similarities than differences with the rest of the animal kingdom, but that human beings are nothing but machines made out of flesh and controlled by the same physical mechanics that are found in a clock.[238] Thus, the body is nothing but material organised in a very complex and integrated manner. Sometime later, in the nineteenth century, the human body was then compared to a hydraulic system, with capillaries, circulatory systems and pumps. At present, with the development of computers and software, it is often compared to a biological computational machine, with the DNA acting as the software.

These representations of the human body initiated a number of conceptual questions in philosophy and anthropology, such as whether it may be possible to enhance humanity without the use of an agreed external reference framework of what it means to be human. Questions also existed between the functional and holistic concepts of humanness, between the external and internal changes as well as between any gradual and radical alterations. In addition, it may be difficult to distinguish between changes primarily related to medicine and those seen as personal preferences, since there may be a substantial overlap and ambiguity between the two. This means that every change to the human body must be examined on the basis of ethical theories and principles in order to consider whether it may be seen as acceptable, while considering its potential impact, including its consequences on society.

In this regard, in 2005, the European Group on Ethics in Science and New Technologies to the European Commission indicated that: 'The ethical notion of the inviolability of the human body should not be understood as a barrier against the advancement of science and technology but as a barrier against its possible misuse.'[239]

As such, it may also be important to consider whether a relevant difference exists when a device is present inside or outside the human body. Indeed, from a psychological and social perspective, human beings consider the human body as the defining boundary and entity of the human person on which many of society's customs and laws are based. [240] For example, if a mechanical heart is placed inside a person, this could then be seen as an integral part of his or her human body. No one would then be entitled to take it out against the will of the individual. On the other hand, if the same heart was placed outside the body of a person, a different perspective may arise from an ethical, anthropological and legal standpoint.[241]

This becomes even more complex when neuronal interfaces are considered. As the American theological ethicist Ronald Cole-Turner indicates: 'We are embodied creatures, and any use of technology that affects any part affects the whole being, including the very core of identity and personality, our mental powers of memory, understanding, and will.'[242]

Moreover, if a direct neuronal interface was used to fuse a human being's brain to a computer, enabling him or her to think online, then the element of consciousness within the computer would become an extension of the human being's own consciousness, which had been enhanced through the interface to the computer. In other words, the person's own consciousness would be controlling the extended consciousness within the computer so that the person remains human and the computer remains a machine.

However, if the consciousness in the computer begins to exist without any input from an external human brain through an interface, the computer consciousness could then be considered as a computer person who would be completely different and independent from human life as such. This would mean that the personal psychological identity of an individual, his or her self, could slowly and indistinguishably evolve to become another being through his or her interface with a computer and cyberspace. A clear demarcation line would no longer exist between the computer and the human person. In this respect, Cole-Turner argues that 'as we turn technology on ourselves so that we change our own bodies and brains, the "I" is swept up in the change and modified through its own action. When these technologies of human enhancement get inside us, they become part of us, turning us into our own products and blurring the lines we once drew between subjects and object, agent and effect'.[243]

This, in a way, also reflects the philosophical idea of 'mind extension' which suggests that the mind cannot simply be seen as something that is resident in the brain since it can, in various ways, spread out instead into its surroundings, merging with other things, places and other minds. As such, Andy Clark, who is one of the leading philosophers of mind extension, indicates that:

> New waves of almost invisible, user-sensitive, semi-intelligent, knowledge-based electronics and software are perfectly posed to merge seamlessly with individual biological brains. In so doing they will ultimately blur the boundary between the user and her knowledge-rich, responsive, unconsciously operating electronic environments. More and more parts of our worlds will come to share the moral and psychological status of parts of our brains.[244]

The Canadian computer scientist and futurologist Hans Moravec even indicates that it may, in the future, be possible to connect a human brain to a computer in such a way that 'in time, as your original brain faded away with age, the computer would smoothly assume the lost functions. Ultimately your brain would die, and your mind would find itself entirely in the computer'.[245] This means that when the human body eventually decays, this brain–computer information exchange may be able to preserve the essence of self-consciousness, personal histories and creative abilities.[246]

Another interesting area of research is computer-based brain simulation, whereby neurobiological systems are used as models to create a computer imitation of the entire brain, making it possible for a new digital mind to emerge. As the U.K.-based bioethicists Sarah Chan and John Harris note: 'The question is whether a computer that simulates the whole human brain to a sufficiently realistic degree would become, in some sense, a human mind or indeed any other sort of mind.'[247]

But could a nonbiological entity lacking any of the human physical attributes ever be considered a 'human' being? Kurzweil believes that any new human-like artificial intelligences that could evolve through such a process will be 'human even if they are not biological'[248] and suggests that the term 'human-machine intelligence' should be used to highlight this fact. In this way, Kurzweil's main argument for the humanity of machine intelligence is that it has evolved very slowly from beings who are undoubtedly human.[249] There would then be 'a world that is still human but that transcends our biological roots' in which 'there will be no distinction . . . between human and machine or between physical and virtual reality'.[250] Yet, as already indicated, no definition of what is human exists and it is therefore difficult to set any limits to what is human.

Similarly, it is difficult to say whether or not persons are human if they are conscious inside a computer. They may certainly be persons with a consciousness but may not be categorised as human persons. Their bodies would be computers, but would their minds be similar to those of human beings? It would also be difficult to state, with any certainty, whether such computer persons are alive.

Another possibility is to just consider the new being as a nonhuman person if it is able to think like a human being. But, of course, this comes back to asking how it is possible to know whether a computer has become conscious, especially since, as already indicated, it is very difficult to even quantify consciousness.[251]

It is also important to ask whether the value that is accorded to human bodies, including the human brain, may be diminished with such technology. This raises the question whether the human brain can simply be compared to a machine that has little value in comparison to the mind of a person – a mind that could also exist inside a computer hard disk.

In short, whilst there is much to celebrate in terms of advances made in the field of science and technology, it is becoming increasingly apparent, particularly in the field of neurotechnology, that human bodies and brains are quickly becoming projects to master, take control over, design and fuse according to humanity's own desires. Therefore, it is crucial to consider how far such neuronal interfaces can challenge and impact concepts of human integrity and dignity.

The Transhuman and Posthuman Body

It is now possible to envisage a future in which parts of the human body are substantially replaced or upgraded by machines (generally defined as transhumanism) or where the body no longer even resembles, in any way, that of a human person (generally defined as posthumanism).

This of course will have significant repercussions on biological or physical anthropology and may even completely transform the whole discipline.

Transhumanism

The proposal that humanity should use technology to go beyond the restrictions of the present human body, including the brain, was described as 'transhumanism' by the British biologist Julian Huxley (1887–1975), who was the brother of Aldous Huxley (1894–1963), the author of the 1932 book *Brave New World*.[252] He used the term for the title of an influential 1957 article, though the word itself derives from an earlier 1940 paper by the Canadian philosopher William Lighthall (1857–1954).[253] In this article, Julian Huxley described the aims of transhumanism as follows:

> Up till now human life has generally been, as Hobbes described it, 'nasty, brutish and short'; the great majority of human beings (if they have not already died young) have been afflicted with misery . . . we can justifiably hold the belief that . . . the present limitations and miserable frustrations of our existence could be in large measure surmounted . . . The human species can, if it wishes, transcend itself – not just sporadically, an individual here in one way, an individual there in another way, but in its entirety, as humanity.[254]

Julian Huxley explored developments in ecology, genetics, palaeontology, geographical distribution, embryology, systematics and comparative anatomy, which he outlined in 1942 in *Evolution: The Modern Synthesis*.[255] However, the ideas behind transhumanism and the enhancement of humanity can be traced back to the Enlightenment ideology of promoting technological changes as the engines of human progress. This included writers such as the French encyclopaedist Denis Diderot (1713–84), who was a leading member of the Enlightenment.

In more specific terms, transhumanism can be characterised as a multidisciplinary cultural phenomenon consisting of beliefs, norms, literature and social practices addressing not only scientific and technological changes but also deeper human existential concerns. In fact, it can be considered as an ideology of ultimate progress aiming at delivering humanity from the limitations of human nature, including the biological, mortal body. In other words, it welcomes technology as the main driving force of cultural change.[256] It offers a vision of the right moral ordering of self and society in relation to a technology-driven global transformation. This means that transhumanism signals a shift from the human to the transhuman existence, as well as actions and beliefs that will promote and influence the optimal transhuman future.[257]

It follows that transhumanism is different from the concept of enhancement in that it seeks to create beings who have never previously existed in the history of humankind. But these beings would retain some human characteristics, such as with human-nonhuman interspecies beings or cyborgs that combine the human with the robot. For instance, the Cybermen of the BBC fictional television series *Doctor Who* used a process called cyber-conversion that involved replacing the human flesh of a person with cybernetic upgrades in order to increase their numbers rather than using biological reproduction.[258]

Similarly, the 1952 science-fiction novel *Limbo*, written by the American Bernard Wolfe (1915–85), depicts a challenging future where human body parts are replaced with cybernetic limbs, while examining what happens when the limits of the body and what is natural are overcome.[259]

In other words, transhumanists agree that human nature is not fixed and that the human species can change over time beyond its biological limitations. Some would also accept a future where sexual reproduction becomes obsolete because it is replaced with technology.[260]

However, it is difficult to know where to draw the line between humans and machines if a person has been changed through technology. Indeed, it is possible to ask whether a human being with an important artificial neuronal implant is still a human.[261] These are dilemmas that will continue to evolve in modern society in the light of new possibilities.

But even if a human brain eventually becomes mostly nonbiological, humanity is likely to retain an overall notion of what constitutes beauty with regard to the human body, as this is deeply embedded in human values. Until now, when persons are considered to be physically good-looking, this is generally seen as a measure of their biological health, intellectual competence and even moral balance, which may be useful in increasing their reproductive chances and of having descendants. Yet, given that the human body may change over time, ideas of what is considered beautiful may also change.[262] In other words, if reproduction becomes nonsexual or even nonbiological in the future, a different sense of beauty may emerge.[263]

Transhumanism can also be compared to an understanding of the 'end times' when the human species will both transcend itself and bring about its own planned obsolescence. As Julian Huxley indicated, transhumanism is a 'religion without revelation'.[264] But there are significant differences between his beliefs and those of contemporary transhumanists, who are usually only interested in using technology to develop the human species.

Transhumanism also offers an ethical vision in which technological innovation is the central human achievement and thereby becomes the medium for achieving authenticity, liberty and justice.[265]

However, transhumanists may be somewhat disingenuous when claiming that they strive for immortality and, at the same time, see themselves as the descendants of humanists. This is because humanists generally consider humanity as a 'good' and would not accept the transformation of the human species into something that is no longer human. Many humanists believed that being human is the pinnacle of evolutionary achievement and would not want to replace this humanity with anything else. With transhumanism, on the other hand, the state of being human is merely a stage in the evolutionary process towards a higher 'good', though there is often no indication about what this actually represents.[266] This implies that transhumanists cannot be compared to humanists in any meaningful way.

Posthumanism

Possible future posthumans may be distinguished from transhumans in that they would have evolved from humanity, but their basic capacities so radically exceed those of present human beings as to no longer be considered as human in any significant degree or form.[267] In other words, though cyborgs may be characterised as transhumans, since some parts of their bodies remain human or resemble those of humans, with a posthuman nothing of the human body is usually left.

Generally, however, it is difficult to accurately describe the posthuman. In her 1999 book *How We Became Posthuman*, the American author N. Katherine Hayles characterises such a subject as 'an amalgam, a collection of heterogeneous components, a material-informational entity whose boundaries undergo continuous construction and reconstruction'.[268] In this regard, she suggests four different aspects of a posthuman future:

1. The prioritisation of information pattern over material substance.
2. The acceptance that consciousness is simply a mere product of the physical.
3. The recognition that the human body is just an original form and substance of a being that can be upgraded or replaced.
4. The acceptance that human beings can just be compared to intelligent machines, making the two interchangeable.[269]

It is also unclear how a specific identity is formed in the posthuman. As Hayles indicates:

> [T]he presumption that there is an agency, desire, or will belonging to the self and clearly distinguished from the 'will of others' is undercut in the posthuman, for the posthuman's collective heterogeneous quality implies a distributed cognition located in disparate parts that may be in only tenuous communication with another.[270]

As such, Hayles accepts that the posthuman body has becomes difficult to define, while noting that William Gibson characterises such bodies as 'data made flesh' in his 1984 book *Neuromancer*.[271]

The combination of pop science and science fiction in the spread of posthumanism was persistent throughout most of the twentieth century and has helped to drive forward much posthumanist thought.[272] But it is still impossible to really know what a posthuman future will look like. It will, apparently, have its origins in the aims of transhumanism and will continue to build on the belief that, through science and technology, humanity can take charge of its evolutionary destiny by redesigning itself in its own way.

Science commentators, such as Kurzweil,[273] Moravec[274] and the Australian artificial intelligence expert Hugo de Garis,[275] hypothesised that the merging of human and machine would herald further evolutionary changes in the human species in which technology, in particular super-intelligent machines, will not only enhance the physical and mental capabilities of, but will eventually replace, the humans who designed them. These commentators postulated that the posthuman 'Mechanical Age' will begin after an irreversible turning point takes place caused by an increasing acceleration of technological growth. This has been called the Singularity, which the American science commentator Robert Geraci explains is 'a point of the graph of progress where explosive growth occurs in a blink of an eye' when machines 'become sufficiently smart to start teaching themselves'.[276] When this happens, 'the world will irrevocably shift from the biological to the mechanical' and the 'Mechanical Age' will inaugurate the 'New Kingdom': the 'Virtual Kingdom'.[277]

According to Moravec, the human race will then be replaced by self-aware computer-robotic beings who will be able to escape this earth.[278] In his 1999 book *Robot: Mere Machine to Transcendent Mind*, he explains that:

> Our artificial progeny will grow away from and beyond us, both in physical distance and structure, and similarity of thought and motive. In time their activities may become incompatible with the old Earth's continued existence.[279]

He adds that:

> An entity that fails to keep up with its neighbors is likely to be eaten, its space, materials, energy, and useful thoughts reorganized to serve another's goals. Such a fate may be routine for humans who dally too long on slow Earth before going Ex.[280]

Kurzweil's predictions of the technological Singularity occurring at about the year 2045 could not be more significant: 'The Singularity will allow us to transcend these limitations [such as slow information processing] of our biological bodies and brains. We will gain power over our fates. Our mortality will be in our own hands.'[281]

In this scenario, technical imagination promises the preservation of humanity while putting an end to the main problems associated with the biological human body.[282] This also means that those promoting a posthumanist future would generally welcome the demise of the *Homo sapiens* species so that it can be replaced with posthuman beings.

At the heart of the posthuman dream is the use of technology to discover and master, in precise detail, how the mind works and what memories represent. Using this information and data, it is then proposed to capture every bias in opinion and effectively catalogue every mood. This could subsequently be transferred onto some yet-to-be-developed supercomputer in which the person could continue to exist.[283]

This change from biological humans to super-intelligent machines, capable of making decisions, will progress slowly. To begin with, it is suggested that humans will upload the most important parts of their minds and personalities into supercomputers, which will look after the physical needs of humanity. Eventually the machines, in the words of Geraci, 'will tire of caring for humanity and will decide to spread throughout the universe in the interest of discovering all the secrets of the cosmos'.[284]

Similarly, Moravec postulates that machines will convert the entire universe into an extended thinking entity.[285] Eventually, when the 'Age of Mind' replaces the 'Age of Robots', machines will create an environment for a 'subtler world'[286] in which only calculations continue to exist. The Virtual Kingdom will eventually make earthly life futile and will ultimately be engulfed by cyberspace.[287] This is the ultimate goal of the metamorphosis of the human to the posthuman. Technology will enable humans to successfully bring about what established religions have sought for thousands of years: immortality.[288] According to Kurzweil, '[o]ur mortality will be in our own hands. We will be able to live as long as we want', which, interestingly, is not quite the same as immortality.[289]

Cyber-immortality is especially supported by the American sociologist William Bainbridge, who presents posthumanism as a kind of religion for the 'galactic civilisation'.[290] He also asks humanity to be creative so that the current virtual world 'could evolve into extrasolar homes for posthuman beings'.[291] In this context, he defends the notion of technologically based immortality, predicting that it 'will put religions largely out of business, and [therefore] religious fundamentalists would condemn activities in these directions'.[292]

Of course, the dream of cyber-immortality is currently more science fiction than fact. But it does emphasise the desire in the technological sector to consider computers as a way to break free from the constraints of bodily existence.[293] Because of this, Bainbridge considers that if the contents of any personality archives were to be 'erased', this could be a form of murder, an 'infocide', because it would kill people in their pure form.[294]

Hayles also examines how poshumanists have asserted the importance of freeing themselves from the limitations of nature to build a more favourable posthuman future with a new social and political order.[295] The vision is of a perfect world, free of suffering, where freedom is the dominant value and where persons would have unlimited opportunities for individual and community development.[296] On this account, virtual reality is often seen as the future for a posthuman world – not as a means of escape from the real world, but rather as a means to change what is real for the better.[297]

It is interesting that the posthumanists use a language of tolerance and open-mindedness. But Hayles argues that the transition from human to posthuman may not be consistent with these liberal principles.[298] The philosophy of autonomy, freedom and rights relies on the reality that the individual is a distinct being with clear and lasting boundaries separating one individual from another, particularly in the case of a biological human with a distinct identity. But in a posthuman future, it may be necessary for these borders to become moveable and immaterial. In fact, for posthumanists, technological change requires that all boundaries be easily altered.[299] For example, in a posthuman existence, there is no fixed boundary between a bodily brain existence and any other kind of existence that can be supported by a computer. There is also no separation between humans and their environment, between the entity that thinks and the entity that is being thought about, and no inherent division between mind and matter.[300] A biological brain is not seen as necessary and configurations of information are more important to the state of being.[301]

But how can this moveable network of information maintain an individual's identity? What exactly remains of an individual when these networks are constantly changing and developing? Indeed, many new identities would be created if the entire minds of human beings are copied on to a computer. Will they then merge into a single conscious being? Within this arrangement, the posthuman is not simply an extremely enhanced autonomous being, since the very existence of posthumanity may require destroying the actual basis of autonomy, individuality and personal freedom, which determines liberal, humanistic agency.[302]

Ethical Consequences for Human Persons

In this context, it is very important to seek to determine what the ethical implications of such profound changes may be. Many of the posthumanist values are similar to those found in the already mentioned second-century religious movement of Gnosticism, where followers rejected the material world to only concentrate on what was spiritual.

But St Irenaeus, a second-century Christian bishop of Lyon (central France), argued that the Gnostic position of disdaining the body, including the brain, led to two conflicting ethical positions. The first was that a moral stance of liberty to physical experiences could develop because a human body was no longer considered as really belonging to a person. Thus, if it was no longer seen as being an important part of a person, then it did not really matter what a person did with it. The second position was one in which extreme austerity could be demonstrated towards the body. A person would then be able to express or reveal the insignificance of the body by neglecting it.

In more modern times, societal positions may not be all that different, with a sense of scepticism developing towards the human body and the belief that it may not be an important part of who a person really is. This is because either persons have full control over their bodies or these bodies have full control over them.

As the British theologian Geoffrey Wainwright writes: 'We live in a very sensate and sensualist society. We are in some ways absorbed in our senses, a people defined by materialism and sexuality. Yet in other ways, we are curiously detached from our bodies, as though we were not really affected by what happens to us in our bodies or what we do in them.'[303] He goes on to draw the conclusion that: 'If our bodies are not us, then we are not responsible in and for them; and that irresponsibility may assume the character of either licence or, indeed, of withdrawal. The same phenomenon occurred in the gnosticism of the second century.'[304]

If this is the case, then persons may not need to worry about the way in which their bodies are used. But an alternative perspective can be suggested, which considers the body (including the brain) as being very important to the psychosomatic whole human person and should therefore be treated with respect and dignity. Indeed, it is through the body that human beings identify themselves with other similar beings and are the holders of rights. As a result, human bodies can be considered in a positive manner, which implies that human beings should seek to respect, care and look after them.

This view emphasising the integrity of the psychosomatic person is supported by the Council of Europe Convention on Human Rights and Biomedicine, which indicates in Article 1 that:

> Parties to this Convention shall protect the dignity and identity of all human beings and guarantee everyone, without discrimination, respect for their integrity and other rights and fundamental freedoms with regard to the application of biology and medicine.

This means that if the whole concept of what it means to be human, as such, is undermined, it may jeopardise the protection for the dignity, integrity and identity of all human beings, meaning that the very basis of civilised society would be endangered.

Uploading a Mind

The possibility of uploading a mind has often provided inspiration for science fiction. The 2014 film *Transcendence*, directed by the American Wally Pfister, is one such example. The film's storyline centres around Dr Will

Caster, a researcher in the field of artificial intelligence whose work focuses on creating a sentient machine that combines both the collective intelligence of everything ever known alongside the full range of human emotions. Not surprisingly, such work brings him much applause but also criticism from anti-technology extremists, who eventually attempt to kill him. However, this only makes Caster more determined to succeed in uploading and transcending himself into a computer. As his thirst for knowledge develops into a seemingly omnipresent quest for power, the key question in the minds of his fellow researchers is not whether omnipresence can be achieved, but whether it should even be attempted.

The film is interesting because at the very heart of the posthumanist philosophy is a vision of a future in which human (or transhuman) beings will be able to copy human minds into a new setting and transcend human biology. As already indicated, it was Kurzweil's critically acclaimed 2005 book *The Singularity is Near* that presented a detailed scientific explanation for how this may one day be achieved. He suggested that such a move would involve re-instantiating the mind's state in a different, much more powerful computational substrate. Kurzweil then perceives that human beings 'will continue to have human bodies, but they will become morphable projections of our intelligence'.[305] He goes on to explain:

> Combining human-level pattern recognition with the inherent speed and accuracy of computers will result in very powerful abilities. But this is not an alien invasion of intelligent machines . . . we are creating these tools to make ourselves smarter. I believe that most observers will agree with me that this is what is unique about the human species: We build these tools to extend our own reach.[306]

As a result, it is suggested that the severe limitations of being human will be superseded and overcome. Rather than just existing in the physical dimension, these 'software-based humans' will be able to leave human bodies behind and live out their lives or even attain immortality in virtual reality by having the potential to project their existence whenever and wherever this becomes necessary.[307] In a way, such an understanding of the self is similar to the one developed by John Locke, who wrote that the 'self is not determined by Identity or Diversity of Substance, which it cannot be sure of, but only by Identity of consciousness'.[308]

For Kurzweil, attaining the goal of uploading human minds into human-made machines is a significant milestone in reaching a posthuman future. Whilst the finite, limiting body will die, the software of a person's life, his or her personal 'mind file', will continue to survive in silicon format, while holographic avatars could interact with other bodiless posthuman entities.[309]

Practical Challenges

Before attempting to grasp the process of mind uploading and brain simulation, it is necessary to appreciate how the human brain transits and processes information. As already mentioned, neurons are cells that transmit electrical nerve impulses, carrying and processing information from one part of the body to another. Their spider-like shape of a central body with spindly legs, formed by axons and dendrites, is crucial to their function. The legs branch out repeatedly until they create up to 10,000 endings, which reach out and make contact, at a point known as a synapse, with other parts of the same neuron or with other neurons.

A fully developed healthy human brain has around one trillion (10^{12}) neurons. If each of these has 10,000 synaptic contacts, this gives the brain 10 quadrillion (10^{16}) possible connections. Through the ageing process, some of these will be lost so that by adulthood, an individual would only have about one quadrillion connections. Though there remains much debate upon the exact figures at stake, engaging in the process of simply counting these connections would be a task that any computer would find impossible to achieve either at present or in the near future.

If this was not difficult enough, synaptic connections are also constantly forming, strengthening, weakening and dissolving. This permanent state of flux helps create a complex web of connections that clearly challenges any replicating procedure.

Kurzweil estimates that the brain's billions of interconnected neurons can perform 10^{16} calculations per second (cps).[310] In order to capture in detail all the connections between neurons required to successfully upload a human mind into a computer, represented by a single binary number (0 or 1), called a bit, Kurzweil boosts his estimates to 10^{19} cps.[311] Thus, with the eager anticipation of being able, one day, to successfully copy a human mind into a computer, he proposes that 10^{18} bits should suffice to represent all the inter-neuronal connections required. The scale of the numbers is fantastic, but Kurzweil perceives these to be achievable based upon the law of accelerating returns, whereby he predicts that supercomputers will eventually match the computational power of the human brain.[312]

However, in order to reach Kurzweil's goal, engineers will require not just the ability to make machines that think, but think as well as humans.[313] This requires the software of human thought to be mastered, which is something that has only just begun to be considered through advances in computational power.

In addition, it is possible to ask whether simply matching the human brain's neuronal network and computational power is the only challenge to copying a human mind into a machine. What about perceptions, memories, sensations and intentions? How do these relate to the neuronal network and how can they be successfully replicated?[314] Indeed, a full description of the human brain would be required, which must take into account the many different levels of activity. For example, it is possible to imagine a scale where perceptions, memories, meanings, sensations and intentions are found at the top levels of activity and where neuronal maps and circuits comprising collections of neurons are found at the lower levels. Within this scale, a level of organisation would also be necessary, consisting of individual neurons and the connections between them.[315]

Achieving Mind Upload

Kurzweil's belief in transcending biology presents a view of humanity's essential properties being maintained post-uploading. According to the concept of 'patternism', human beings are essentially patterns that can be realised either biologically or electronically.[316] Preserving the relevant patterns of the individual ensures that memories, beliefs and other mental states are transferred from the biological brain to the electronic medium.[317] This would also require a computer that is capable of genuine thought to support the uploaded mind.[318]

If this eventually becomes possible, it has been suggested that uploading could then be similar to undergoing surgery, whereby a person temporarily loses consciousness under general anaesthetic, but then awakens afterwards. In the case of mind uploading, a similar break in conscious experience could occur, whereby the person would subsequently recover his or her existence in virtual reality.[319]

Kurzweil indicates:

> My leap of faith on identity is that identity is preserved through continuity of the pattern of information that makes us us. Continuity does allow for continual change so whereas I am somewhat different than I was yesterday, I nonetheless have the same identity. However, the continuity of the pattern that constitutes my identity is not substrate-dependent. Biological substrates are wonderful – they have gotten us very far – but we are creating a more capable and durable substrate for very good reasons.[320]

But how is it actually possible to copy human minds into virtual reality environments? One answer that Anders Sandberg proposes for nondestructive data acquisition uses the potential of nanotechnology and nanomachines. The brain could then be flooded with these nanomachines, which would, individually, plug into each neuron, allowing them to find out what that neuron is doing. This information would then be fed back through a wireless or optical network to an external appliance, where the information and data would be collated and processed. Though only a theoretical proposition, experts in molecular nanotechnology believe that this could eventually be feasible.[321]

Plans are also in preparation to create a human brain atlas as an important starting point for interpreting data from other brains.[322] This would involve freezing a brain with liquid nitrogen and then carefully slicing it and scanning each slice with an extremely powerful microscope. These scans would subsequently be fed into a computer alongside extensive image analysis, which would help determine the activity and processes of the neurons.[323] But, once more, extensive computation power would be necessary to process this level of complexity.

Interestingly, in 2013, an international group of neuroscientists were reported to have already sliced, imaged and analysed the brain of a 65-year-old woman to create the most detailed map yet of a human brain in its entirety. Named 'BigBrain', the atlas shows the organisation of neurons with microscopic precision, which could help clarify or even redefine the structure of brain regions obtained from previous anatomical studies. Such a method may completely change the stakes relating to the possibility of identifying very fine structural and physiological differences in the human brain.[324]

Should the full procedure described by Sandberg ever be achieved, one significant question still being debated by experts is whether the system would experience consciousness in the same way as the original human individual. Sandberg believes that if everything is done properly and all the science is well integrated, it may be successful.

On the other hand, Moravec considers that, initially at least, mind uploading efforts would require a gradual destroying of the brain. But as the process continued, an increasing amount of an individual's thinking would be undertaken by the computer until it would completely replace his or her old thinking in the brain.[325]

In addition, if brain scanning ever became possible, it would be necessary that no changes or mistakes occur during the procedure, otherwise the original mind would not be replicated into the computer. Another mind would be created. But maybe making such amendments to a scanned mind could also become deliberate if there was a perceived advantage for this to happen.[326]

In the light of all this, Geraci indicates that: 'Whether digital technologies can live up to their utopian promises is an open question, and not one subject to empirical analysis.'[327] However, he notes that advocates of mind uploading, and other technologies, rely upon what they consider to be indisputable guarantees for such a possibility, such as through evolution or a law of accelerating returns.[328] In the end, the only actual demonstration that technology may eventually address human limits will be for that event to actually occur.[329]

The Existence of Uploaded Minds

In the very unlikely event that the information making up a mind could be scanned, copied and uploaded into a computer, new possibilities arise that need to be discussed.[330] For example, it may become feasible to download this mind into various biologically engineered, robotic or virtual settings. Human persons, as human embodied creatures, would be a thing of the past! They would then become virtual persons whose minds would no longer be supported by biological brains and for whom spatial and temporal constraints would no longer exist.[331]

In this respect, if the end result was virtually immortal personalities processing an infinite number of experiential inputs, the price may be worth paying for some. Different virtual persons could then be combined and/or new ones formed. These new minds would then be able to control their own destiny while also contemplating the possibility of creating their own virtual children.

If individualities were to remain in existence in this virtual setting, they would form what has been described as monads – in other words, self-contained and secluded nonmaterial entities with no spatial or physical properties expressing rational or autonomous activities. These monads would then exist as independent points of vital willpower and as surging drives to achieve their own goals according to their own internal dictates. This implies that the monads would remain as individuals, whatever such a concept means in a cyber-setting. The mental life of the solitary monad (which has no other life) would then express a procession in a series of internal representations,[332] while still interacting with other monads because otherwise it would have no projects and inputs to process.

Monads, therefore, would exist within a network of interactions that do not include any kind of objective realities. They merely interface with various representations or interpretations and experiences that can be stored, simulated, manipulated and discarded. As Brent Waters indicated:

> The monad is a composite of surrogate experiences based on sensual perceptions that must be interpreted, reconstructed and projected back. Strictly speaking, there is no physical contact among monads, for physicality as such is also a projected construct, and thereby illusory. Consequently, there is nothing but perception on the rapidly changing monadic landscape.[333]

In this context, the activities and existential experiences of autonomous monads could be coordinated and brought together by a central and infinite monad that could be known as God. This would represent, and be comparable to, a central nervous system in a complex organism, enabling each monad to pursue its separate life according to the free will decisions of its own deliberative nature, while remaining harmonised with all the other monads online.[334]

As a result, each monad would be a microcosm making up a macrocosmic individuality through a meta-network.[335] But the way in which these two levels of individuality would work remains uncertain. Indeed, questions remain whether monads in a meta-network could be considered as individuals as such, and whether individuality would even persist.[336]

Moreover, if they do persist in cyberspace, any distinction between reality and virtuality would disappear. As a result, cyber-individuals could even be trapped in an existence in which virtual dangers and nightmares become as real as their own reality. This was developed in the already-mentioned science-fiction film *Tron*, in which a computer programmer becomes trapped in a terrifying cyber-existence.

Something close to the notion of mind uploading and monads is very briefly mentioned by the American writer and biochemist Isaac Asimov (ca. 1920–92) in his 1956 short story *The Last Question*, in which: 'One by one Man fused with . . . [the supercomputer], each physical body losing its mental identity in a manner that was somehow not a loss but a gain.'[337]

A universal consciousness, or a kind of hive mind, could then emerge, which would only be limited by the universe itself. This could be considered as a form of super- and supra-intelligence with a wonderful breadth and width of capacities. But this will be further examined below in the 'Network Consciousness' section.

Identity Questions

With mind uploading, it is possible to ask how it would be feasible to demonstrate that what had been created was really a human in a computer. For many, the Turing test remains the experiment of choice for such a conundrum. Proposed in 1950 by the British mathematician Alan Turing (1912–54), the test sets out a means to assess whether a computer could imitate a real human being.[338] A machine is said to have passed the test if a human judge cannot tell whether he or she is having a conversation with a person or a machine. However, the key problem with this test is that one will always be left wondering whether there was not one more question that could have revealed a distinction. A final conclusion may thus never be achievable.[339]

Ethical concerns relating to uploading a mind into a computer also include the fact that mechanical decision-making by the computer may be considered far superior to the decisions made by human beings.[340] Moreover, such uploading would certainly challenge the concept of personal identity and have implications for the meaning of personhood.

Finally, because the loss of the individual human body would have a significant impact on the way in which an individual interacts with other human beings, various sets of ethical questions may be considered:

- Since backups of a person would need to be created to protect against viral attack or sudden catastrophic failure of a main drive, how can an individual be sure that these are safe and secure?
- Could the backups, themselves, be considered as persons brought into existence through a copying procedure of the original person?
- Who has access to these backups then becomes a significant question as a breach of security would be cyberspace's equivalent to a forced entry or personal trespass. The lack of privacy and of informed consent to the involuntary disclosure of information would also become a real problem. Hacking, in this scenario, would be a personal invasion on an altogether new level, perhaps putting it in the same category as other violent invasive crimes such as rape.
- Questions can also be asked about what would happen if the backups and the files expressing a person were irreversibly lost. Would this then represent a form of death of the individual?
- Backing up could, in addition, enable a person to relive certain experiences. If one day did not turn out quite how he or she had planned, the individual could return to the beginning of the day and go through it again. However, this would require the person remembering that he or she had chosen to relive the day, otherwise he or she might become trapped in a never-ending loop. Moreover, if an individual was able to return to happier versions of his or her life, would it really matter? Would anyone actually know? And even if they did know, would they care?
- Reliving in a computer may be meaningful only as long as the person does not interact with another uploaded being. Otherwise, this first person's existence and electronic actions would become part of the timeline and experience of the second individual's memory and cyber-experience. In other words, it would not be possible for the first person to delete his or her experience without requiring the second person to delete his or her own memories as well. This means that existing in a computer might enable a person to stop ageing, but this cannot assume that the clocks of cyberspace have stopped.[341]
- How would concepts such as compassion ('suffering with' in Latin) and empathy ('feeling in' in Greek), which make existences meaningful, be able to be expressed in digital persons, since these notions require a capacity to suffer? It is also possible to ask how such a capacity to suffer in computers could be developed. This is especially relevant for higher levels of suffering, such as that arising from existential fear, which may be necessary if life is

> not to become a dystopia of programmed, meaningless and robotic happiness. Being able to suffer with others is maybe what makes human beings most interesting!

As already noted, these are not necessarily new philosophical questions. The idea of having a material, physical body and disembodied thoughts is a concept much loved by dualist philosophers such as the seventeenth-century philosopher Descartes, but criticised by many since.[342]

Finding Meaningful Virtual Existence

A meaningful existence in a posthuman cyberspace future may be considered as natural and even necessary if it is accepted that evolutionary selection will favour artificial intelligence over human intelligence and if the spread of computational technology is declared inexorable. As the religious commentator Hava Tirosh-Samuelson emphasised, the 'saviour' of this new 'religious order' is clearly technology. However, this is rooted in the belief that human beings will benefit because computers will solve 'human problems, and when human beings upload their minds into machines, they will not only live longer, happier lives, but they will also attain immortality, the very end that traditional religions promised their adherents'.[343]

In theory, virtual worlds and spaces will then create the context within which to outwork this kind of posthuman life, ultimately evolving into the first real afterlife. In a way, aside from the simple fact that they are fun, video games already espouse the transcendent benefits that posthumanism promotes. Whilst, for many, these virtual spaces may just be games, for some, they are of crucial importance and value, helping to provide a template for the future. As Geraci indicates: 'Every player who acclimates to operating within virtual worlds, controlling a character that is simultaneously both identical to and distinct from herself, moves a tiny step toward a future in which mind uploading looks both more reasonable and more plausible.'[344]

In a survey of players of the virtual reality *EverQuest* game, it was reported in 2007 that 22 per cent would choose to live in its fictional world if this was possible,[345] with the American sociologist William Bainbridge noting: 'I would consider a continued existence for my main [*World of Warcraft*] character, behaving as I would behave if I still lived, as a realistic form of immortality.'[346]

Among posthumanists, it was reported in 2001 that 51 per cent would find it appealing to upload their minds into *World of Warcraft* or a comparable game.[347] This is not to say that all who currently engage in video games and virtual reality simulations are wholeheartedly pursuing the posthumanist vision, but many can see the appeal of being able to 'escape' reality and live within such a system.

Nevertheless, the American computer game developer Jason Rohrer is sceptical about the immortality aim suggested by posthumanism. Because of this, he created in 2007 the virtual game *Immortality*, where players can choose immortality and then build structures with blocks. If they grow bored, however, they can quit voluntarily by choosing death. Rohrer openly admits that the game plays with the 'faith' espoused by posthumanism and acts as a thought experiment, while asking questions about the aim and meaning of immortality. He notes: 'We generally assume that immortality is good, just as we assume that death is bad. Of course, universal immortality (all six billion of us) would be physically impractical. But what about individual immortality? What about for you? If you could become immortal, would you?'[348]

The game initiated much online debate including on the Internet site *The Escapist* in 2008, where it was released. Interestingly, many commentators were not so negative about the prospect of immortality and the many options that might be available to those with eternal youth. In fact, some who played the game believed that it strongly supported the case for choosing immortality. But most commentators found that the game failed to fully illustrate the many options that may be available to those with eternal youth, which was the declared preference of a considerable majority. Among the thirty-eight posts in which a position on immortality was taken, twenty-eight favoured it.[349]

Whether or not mind uploading or posthumanist immortality is a realistic possibility, such aspirations did appear to have been important to the online virtual world *Second Life*. Its American creator, Philip Rosedale, suggested that to be limited by the confines of the human skeleton is not something to be embraced[350] and that there was also value in trying to figure out how to escape death.[351] This resonates with his willingness to believe that some posthumanist dreams might be realised. Indeed, he appears to accept, with reservations, the basic premise of mind uploading, claiming that: 'There's a reasonable argument that we'll be able to leave our bodies behind by uploading into virtual reality.'[352]

Body-Mind Questions in Computers

Given the different perspectives and interpretations relating to personal identity, the very possibility that some identities may change if their material supports were modified should also be considered. Bostrom indicates in this regard that: 'Substrate is morally irrelevant. Whether somebody is implemented on silicon or biological tissue, if it does not affect functionality or consciousness, is of no moral significance. Carbon-chauvinism is objectionable on the same grounds as racism.'[353]

But this again leads to questions about how personal identity should be defined. Even if a computer is programmed to indicate that it is self-aware, how would it be possible to know whether it is a fake, an imposter or another representation that bears only a passing resemblance to an original individual?

Experts such as Sandberg dismiss this question, arguing that personal identities are complex. They cannot be clearly and precisely defined and are subject to many changes as a person develops over time. In what appears to be a giant leap of philosophical thought, Sandberg comments that 'if we can handle growing older we can probably handle being translated to a computer'.[354]

A more detailed exploration of the idea, and one in which individual identity is preserved, was described by the British science-fiction writer Arthur C. Clarke (1917–2008) in his 1956 novel *The City and the Stars*.[355] The story is set in a city one billion years in the future, where the minds of inhabitants are stored as patterns of information in the city's Central Computer. These can then be infused into cloned bodies to be relived in cycles of about a thousand years. A number of commentators identify this story as one of the first (if not the first) to deal with the concepts of mind uploading, human-machine synthesis and computerised immortality.[356]

Interestingly, in addition to being downloaded into a body, an uploaded mind would also be able to copy itself into many (even a multitude of) of minds (its clones) as backups or create many new minds (its descendants in time) that are different from itself. But it would be impossible for a mind to be present simultaneously in multiple locations. Each mind location would be a different individual even if such an individual only existed for a few seconds.

In examining the paradox of multiple exact replicas expressing the same identity, the Scottish neuroscientist Donald MacKay (1922–87) indicated that it would seem 'absurd to suggest that what identifies you is imply the information-flow pattern in your nervous system'.[357] This is because a 'conscious experience is embodied in our being activity: neither on the one hand identical with it, nor on the other hand quasi-physically interactive with it'.[358] This means that, for MacKay, copying a human mind into a computer would be tantamount to creating a correlation, not a translation.[359]

Indeed, because the body of the virtual person would be different from that of the human person, it would actually be a different individual. In other words, seeking to upload a human mind into a computer would result in the creation of a new body-mind person who would be a completely different individual from the original human person.[360] It would be like creating a virtual clone with a new body-mind.[361]

A similar argument is given by the British philosopher Derek Parfit (1942–2017) in his 1984 book *Reasons and Persons*, in which he discusses the teletransportation paradox. This is a thought experiment on the philosophy of personal identity and consciousness. He describes a teletransporter machine that breaks up an individual into atoms, copies the information and then sends it to Mars at the speed of light, where another machine re-creates the same individual from local atoms, each one being in exactly the same relative position as the original. Parfit then asks whether the teletransporter is a method of travel for the original individual and whether the person on Mars is the same person as the individual who entered the teletransporter on Earth. Of course, the individual on Mars would have the same memories and mind as the original person back on Earth.

However, the thought experiment continues with an upgrading of the teletransporter on Earth so that the original individual is not broken down into atoms, but is simply scanned and a copy made in Mars. This would enable the original person on Earth to continue to exist and eventually see a copy of himself or herself coming out of the machine on Mars. Because of this, it is then possible to question who would be the original person. Moreover, if the original person on Earth subsequently died, should the replica on Mars care at all?

In a way, this kind of paradox is not new and was raised as far back as 1775 by the religiously trained Scottish philosopher Thomas Reid (1710–96), who indicated in a letter:

> I would be glad to know your Lordship's opinion whether when my brain has lost its original structure, and when some hundred years after the same materials are fabricated so curiously as to become an intelligent being, whether, I say that being will be me; or, if, two or three such beings should be formed out of my brain; whether they will all be me, and consequently one and the same intelligent being.[362]

But of course, such questions only become relevant for those with dualist perspectives of the person and who do not believe that the body and the mind are one single whole. As such, they fail to recognise that it is impossible to retain personal identity when the body and the mind are separated.[363] This means that if a biological mind is uploaded on to a computer, this could be seen as a form of 'mind-cloning', especially if the original biological mind remains in existence.

Given this perspective, it is interesting to note that Sandberg prefers to use the term 'whole brain emulation' rather than 'uploading'. There is a shift of direction away from translating a person into a new realm, to moving towards an attempt to build something that emulates or imitates a brain. The goal is no longer to enable an existing person to live forever in digital form, but to create a new being based on a more generalised human template – something that is neither human nor transhuman, but certainly highly capable and intelligent.

Network Consciousness

The idea of a collective consciousness was first proposed by the French sociologist Émile Durkheim (1858–1917)[364] in his 1893 book *Division of Labour in Society*. He defined this collective consciousness as the set of shared beliefs, ideas and moral attitudes that operate as a unifying force within society, which includes the concept of the collective memory of the social group. For Durkheim, society is not a group of individuals living in the same geographical place; instead, it is primarily a set of ideas, beliefs and feelings of all kinds, which come into being through the individuals.[365] It expresses a reality that is produced when individuals act on each other, resulting in the fusion of individual consciousnesses. In a social group, each individual's mind is in a relationship with another person's mind, forming a whole interconnected network of all the minds in the social and cultural assembly. Consequently, each person becomes part of his or her own social group, which expresses a sort of cooperative consciousness. In this way, individuals produce a collective consciousness, or a kind of hive mind, through their interactions and this consciousness results in, and holds together, a society.

At the same time, social groups are formed as a kind of multi-individual social organisms in which communication generally takes place through visual or oral means. The cohesive force holding the group together results from a combination of the collective consciousness and the collective memory. A kind of organic solidarity results where individuals become ever more integrated and interdependent, while specialisation and cooperation are extensive.

This reality is also irreducible to its component parts and impossible to explain, except through its own means. In other words, the social group is more than the sum of its parts. It transcends in every sense the existence of any individual and is of a completely different order from the parts of which it is composed. This implies that society and social phenomena can only be explained in sociological terms.

One of the first to suggest a further integration and development of this concept of network consciousness was the French Catholic Jesuit priest and palaeontologist Pierre Teilhard de Chardin (1881–1955), who was a colleague of the British scientist Julian Huxley.

Teilhard de Chardin maintained that human persons were evolving from a state of being individuals to becoming a global consciousness or meta-mind super-intelligence. The 'Noosphere' (from the Greek *nous*, 'mind' or 'reason', and *sphaira*, 'sphere') would then come into existence.[366] In other words, he suggested that when human individuals become ever more connected to this global Noosphere, to which evolution is developing, they would then merge into ever greater and united collectives in which individuality would increasingly be limited in favour of the communion. An emergence of a collective mind of humanity would subsequently take place, which would increasingly integrate the thoughts of all individuals around the globe.[367] This means that the Noosphere would not only be formed by each individual's connected mind, but would represent a greater union as an entity in its own right, a kind of planetarymind.[368] Eventually, this would culminate in an 'Omega Point', which Teilhard de Chardin believed is the goal of history. This is the stage in which a universal mind has been reached,[369] representing the proposed maximum level of complexity and universal consciousness of the Noosphere.[370]

In an essay on the 'Planetization of Mankind', Teilhard de Chardin writes:

> Whether we like it or not, from the beginning of our history and through all the interconnected forces of Matter and Spirit, the process of our collectivization has ceaselessly continued, slowly or in jerks, gaining ground each day . . . It is as impossible for Mankind not to unite upon itself as it is for the human intelligence not to go on indefinitely deepening its thought! . . . Instead of seeking, against all the evidence, to deny or disparage the reality of this grand phenomenon, we do better to accept it frankly. Let us look it in the face and see whether . . . we cannot erect upon it a hopeful edifice of joy and liberation.[371]

According to Teilhard de Chardin, everything within the cosmos is actually converging its purposes through the 'push' of evolutionary forces and the 'pull' resulting from the Omega Point expressed by the affinity that persons have for one another in mutual love.[372] Moreover, for him, this Omega Point at the end of history can be referred to as a person, whom he represents as the Ultra-Human or the Trans-Human [373] and in whom there are global and complex systems of collective self-consciousness[374] that he likens to a 'stupendous thinking machine'[375] – a kind of union with God.

This Noosphere was one of Teilhard de Chardin's most controversial claims and his views were eventually censured by the Catholic Church. Indeed, in a system where each person is completely subsumed by the greater collective consciousness, the notion of independent individuals, with their private lives and their own thoughts, knowledge and opinions, could no longer exist.

However, though there are certain passages in Teilhard de Chardin's writings that seem to suggest that human beings are merely a means to the eventual existence of the Ultra-Human, or a super-organism made up of all human individuals, some vagueness in relation to his thoughts seems to exist at this stage. Teilhard de Chardin's fellow Jesuit, the Frenchman Henry de Lubac (1896–1991), who eventually became a cardinal and defended some of his ideas, admits that this seems like the destruction of personality. But he believed that Teilhard de Chardin was not actually suggesting that individual persons would be swallowed up with the development of the ultra-person; instead, a union of individuals would take place 'centre to centre'.[376]

A number of futurists have sought to compare Teilhard de Chardin's ultimate realm of personal being, the Noosphere, with the Word Wide Web as an emerging global electronic brain where each individual represents a neuron.[377] Indeed, because an ever-increasing amount of personal information is being uploaded to the World Wide Web, this could be considered as a significant step in the evolution suggested by Teilhard de Chardin. The Web could then become the first universal setting of intellectual exchange providing the basis for a complete transformation of the human condition.[378]

A similar idea to Teilhard de Chardin's Noosphere was presented by the British author Peter Russell in his 1982 book *The Global Brain*,[379] where he discusses the prospect of humanity becoming a fully conscious superorganism in a universe that becomes conscious. He suggests that the Earth is itself a living being of which every cell in the planetary nervous system is an individual.

In the *Global Brain* scenario, Russell indicates how telecommunications and computer networks can be considered as connecting all human beings to one another and to machine intelligence, leading to the formation of a collective intelligence. This, in turn, could influence every aspect of culture, politics, business and medicine. He then demonstrates how this convergence of powerful trends is creating the required conditions for an evolutionary shift in consciousness from egocentrism to geocentrism.

This collectivist form of existence was further described in 1993 by the American author Gregory Stock in his book *Metaman: The Merging of Humans and Machines into a Global Superorganism*.[380] In this, he shows how the symbiotic union of machines with humans, combined with increasingly interdependent global communications, trade and travel, is coalescing civilisation into 'Metaman', which again can be represented as a planetary superorganism. With *Metaman*, Stock explains how such an organism can support a positive future when, for example, it responds to emergencies such as global warming and overpopulation, while at the same time expanding future possibilities, such as in genetic engineering, space exploration and medicine.

It can further be noted that the Noosphere has similarities with the 'Borg', which recurs as a supervillain in the American *Star Trek* science fiction film series created in 1966 by the American Gene Roddenberry (1921–91). As such, the Borg is a collection of personal individualities originating from different galactic species who have been turned into a network of cybernetic organisms (cyborgs) functioning as drones for a hive mind called the 'Collective'. Accordingly, all the identities of the different individuals are destroyed when they become absorbed and integrated into this Collective or supra-person. The principal aim of the Borg is to 'assimilate' by force ever more identities into the Collective by violent injection of microscopic machines called nanoprobes. The Borg's ultimate goal is achieving unemotional 'perfection', while indicating in its motto that 'resistance is futile'.

A more realistic development of such collectives has been suggested by the Dublin-based ethicists Fiachra O'Brolchain and Bert Gordijn, who explain that with programmes such as the Silent Talk DARPA programme, 'it is possible to envisage a scenario in which people would collectively participate in a joint emotional/psychological experience'.[381] In such a situation, distinguishing the individual and determining personal agency may become challenging.[382]

Therefore, one important ethical challenge in retaining individual personal agency is making sure that consciousness is maintained, which may itself be limited by the body as the boundary of self. In other words, if consciousness is generated in the brain, a credible theory should be able to account for the way in which individuals experience their bodies as the three dimensional expression of themselves. The bodies of human beings are finite and limited in space, making them specific entities or units. Self-aware individuals are then able to understand that it is possible to transcend their bodies and that others can exist around them.

But if human beings begin to be connected in a very intimate way through neuronal interfaces to become part of a greater collective, their specific bodily limits could be breached. The very ability for persons to understand the possibility of transcending their original bodies would then be undermined. This is important since it would also threaten the limits of a person's sense of individuality.

Another significant ethical challenge arising from a possible communion of minds is that this may only be achievable by the inappropriate mistreatment or abuse of some minds. In addition, a corresponding risk relating to privacy would exist, including a possible undermining of the protection an individual would expect towards his or her past memories, which would be important if he or she wants to retain a sense of self. Thus, such a communion may result in the loss of individuality, which could even mean a loss of individual personal identity.[383] This is something that has already been examined when Greenfield discussed the body of a person, including his or her brain, as 'the boundary of self'.[384] In this manner, a self-aware person with his or her body has, so far, represented the 'centre' of his or her free will. But if this 'centre' with its boundary of the self is lost, the person ceases to exist. Alternatively, if this 'centre' seeks power over others, it may then seek to become the centre of everybody else's free will.

Moreover, if neuronal interfaces do eventually enable minds to be connected together to perform certain tasks, then it may be important to determine whether any decisions are an aggregative phenomenon resulting from the combined decisions of the group or the imposition of one mind over the others. Alternatively, the decisions could be the result of some sort of whole mind system that transcends the contributions of individual members, but is nonetheless capable of intentionality.[385]

These comments demonstrate that it may be very difficult to know what a complete communion or merging of minds in cyberspace would represent. If a person is completely absorbed (and therefore ceases to exist) in the new communion of minds that may only have one consciousness (one new super-organism), then this may represent a form of death for the original person.

On the other hand, if the original person retains some form of individuality, he or she may remain in existence, although this individuality may be permanently violated and exploited by the new super-organism expressed by the communion of minds. In other words, the original person may retain his or her individual identity, but may be forced to conform to what is accepted by the 'communion of minds'.

In a way, this last scenario would be similar to what is already happening with certain human beings when they are controlled, almost digested, by the identity of dominant others, resulting in their free will being entirely overpowered and suppressed (but not integrated out of existence). The stronger, more powerful spirit would then really and irrevocably 'suck' the weaker into itself and permanently gorge its own sense of being on the weaker person's outraged individuality.[386]

Power is indeed about wanting to control the free will of others. There may even be an 'either him or me dominating' concept – a fear of being controlled by, and not in control of, the free will of the other. In other words, a person may want power because he or she is afraid of being vulnerable and suffering at the hands of others, and having total control enables him or her to be protected from vulnerability. This may be one of the reasons why a person may want to have power over others and concentrate all free will into himself or herself.

Alternatively, for some people, the only thing left for them to value may be their very existence and a longing for this to be recognised through having power over all others. Such authority may then represent a search for the esteem of others and thereby a source of self-esteem and self-value. In a way, they want to force all others to recognise their unique existence. Individuals may also be attracted to power for the sake of freedom so that they can do whatever they decide without being restricted by the views of others. Thus, power enables a person to overrule these other views.

This resonates somewhat with the concept of the 'Will to Power' suggested by the German philosopher Friedrich Nietzsche (1844–1900), which is usually understood to mean that the ultimate driving force of a human being is to assert his or her will upon others, though Nietzsche never clearly defined his concept.[387] He indicated:

> My idea is that every specific body strives to become master over all space and to extend its force (its will to power) and to thrust back all that resists its extension. But it continually encounters similar efforts on the part of other bodies and ends by coming to an arrangement ('union') with those of them that are sufficiently related to it: thus they then conspire together for power. And the process goes on.[388]

In summary, the communion of minds into a network consciousness could become the ultimate power (the ultimate Ultra-Human) that one meta-identity could have over many other identities if their free will remains. Alternatively, if the personal identities and free will of a number of individuals are completely subsumed into an existing person or a totally new person (it may be difficult to ever be sure which alternative has taken place), then these original persons would cease to exist.

Issues of Privacy

Even though no consensus exists relating to a general definition of privacy, it can be described as a claim by persons to determine for themselves when, how and to what extent information about themselves can be communicated and used by others.[389]

Privacy is thus important in the context of the kind of relationships or interactions that a person has with people, places and things. People manage relationships with other people through selective disclosure of information, with any breaches in the management of such information having the potential to undermine confidence in the system. Privacy is also about protecting persons from being controlled by others, since having knowledge and information about a certain individual (lack of privacy) can be associated with having a certain amount of power over this person.

In addition, being able to communicate anonymously can be seen as a prerequisite for freedom of expression and can act as an important control mechanism to the abuse of power. For instance, anonymous bloggers can provide an alternative version of the message being presented without the danger of any negative repercussions to themselves.[390]

The manner in which new neuronal interfaces may be able to track and record an individual's thought process may represent a fresh context within which to debate what constitutes private and public life. This is because the increased generation and storing of personal information and data has already proven to be a focus of concern with respect to privacy. For example, questions can be asked about the amount of information being gathered by gaming companies about online players.

In fact, the concept of privacy may be one of the key ethical challenges surrounding advances in new applications of neurotechnology. Indeed, examining the brain and the mind through procedures such as neuroimaging may raise important questions about personal privacy and civil liberties.[391]

However, these concerns are based more upon speculation at present than hard facts, due to the relatively primitive and early stages of development of many technologies such as neuroimaging techniques. Currently, only general mental states such as basic emotions can be detected, along with more specific conceptual/thought patterns. At most, these patterns can be interpreted to form general conclusions about individuals or tendencies within a population. But the end results are little different from other physical indicators of mood or mental state.[392]

With respect to the risks for persons when they increasingly accept to share their personal information, it is worth noting that a significant amount of data relating to many individuals, including children, is already publicly available on the Internet. This is because restrictions are not always present and, if they do exist, a number of individuals may not know how to use them.

As a result, persons who have a lot of information about themselves on the Internet may already have lives that are a lot less private. Consequently, they may become easily manipulated or even exploited by the information gatherers who may use this information against them. The present increased use of information technology is creating real risks of abuse and misuse of personal information, as well as breaches of confidentiality.[393]

But this privacy problem may not be new, since people knew a lot about each other even in the past, when they lived in small communities such as villages. However, in contrast to living in a neighbourhood, the Internet is a global medium and modern persons are not physically close in cyberspace, which may make the virtual world more isolating.

For example, there remains caution and apprehension in the United Kingdom concerning the National Health Service's Electronic Patient Record. In seeking to address these concerns, part of the solution was to ensure that individuals are appropriately informed about the technology, its uses and applications, and have access to the data that is generated. This means that patients must have given their informed consent to the use of personal and medical data. But it cannot be assumed that, when a patient gives an express consent for his or her data to be accessed by certain healthcare professionals and for certain purposes, this consent includes an implied consent for the data to be used by other persons. Nor can it be assumed that it can be used for other purposes that may not be associated with the patient's care and treatment.[394]

Because of such concerns, the Parliamentary Assembly of the Council of Europe suggested in 2017 that transparency, regulation and accountability should be strengthened to address:

– the automatic collection, processing and usage of personal data;
– informing the public about the collection, processing and usage of their personal data;
– informing the public about their right to consent to the use of their stored data and the length of time they are to be stored.[395]

Thought must also be given to the use of personal data as a means of social control, such as in cases of dangerous patients and public health matters. Thus, there may be a need for improved data protection principles and data protection regulations if neuronal interfaces are to be used appropriately in society, such as in a healthcare setting.[396]

Reading the Mind

Despite many developments, what is currently known about the brain and how it works is not yet sufficient to enable a person's thoughts to be 'read'.[397] But this does not mean that attempts are not being undertaken to reach a stage where 'mind reading' could eventually become a possibility. Moreover, transparent communication systems between persons who could then directly communicate between their brains could open up completely new applications. This is also an area of particular interest to military, intelligence and law enforcement communities, where having the ability to decode a subject's intentions, aims and strategies would be an advantage.

In this regard, the convergence of brain imaging techniques, such as EEG and fMRI, is already beginning to enable the identification of neuronal patterns associated with mental states. This is because every thought or perception experienced by an individual can be traced back to a unique and complex pattern of brain activity. By repeatedly tracking this process with the assistance of statistical and computational methods, a certain thought or perception can eventually be associated with a distinct pattern of brain activation in EEG or fMRI. Having identified this pattern, it can then be used to infer or predict future thoughts.[398]

However, significant challenges remain to be overcome. One such problem is that the technology is not currently sufficiently developed to distinguish some of the subtle differences between the vast numbers of brain states.[399] Moreover, each person exhibits a certain degree of individuality and uniqueness in the way in which he or she thinks. This means that differences exist in the neuronal coding between each person's mental state, not to mention the changes in his or her neuronal processing that will develop over time.

That being said, researchers are already able to reconstruct on a screen certain images that research participants are viewing just by examining their brain data. To do this, they created a dictionary of brain activity resulting from those images, which can be decoded in subsequent viewings by matching patterns of brain function with patterns seen in previous viewings.[400]

It is also worth noting that brain scans are increasingly being used in areas other than the medical settings for which they were originally developed. For instance, the commercial use of brain scanning in lie detection is a very profitable field.[401] There have even been repeated attempts to get fMRI[402] lie detection into courts (with some success in India).[403] This includes the 'concealed information test', which makes use of EEG and the relative strength of certain brain waves to determine whether a test subject is familiar with a particular location, weapon or plot.

In the 2013 U.S. television documentary *Brains on Trial*, which explored the potential and the limitations of brain scans in the courtroom, an fMRI scanner was used to determine whether a person's brain recognises photographs of certain faces. Whilst the results indicated that it could, the person was also able to play the machine by pretending not to recognise them.[404]

It is easy to be caught up in the hype surrounding lie detection, but it does warrant more detailed investigation as it remains to be extensively tested with subjects in real-life situations. It could well be that fMRI represents a more reliable form of lie detection than the old polygraph, but this conclusion cannot be proven due to a lack of reliable data. At present, however, fMRI for lie detection have been dismissed as being so error-prone and that it would be irresponsible to use it as reliable evidence.[405]

But other ethical challenges exist in the realm of privacy. The American legal academic and specialist in neuroscience Nita Farahany, though recognising the infancy of brain scan technology, believes that it is important to begin thinking through all the eventual implications. She indicates that her goal 'is to establish a new lens through which to view privacy issues'.[406] This is because there are new questions that demand fresh legal perspectives, since brain scans may eventually undermine traditional notions of privacy. As a result, more protection may be required to guarantee freedom of thought.

Questions also remain about the responsibilities of researchers if, when examining the brain of a person, they can establish that the individual has committed a murder or is thinking about it. Would they then feel obliged to report this information?

Another question that may be considered is whether a brain scan can be accepted as 'physical' evidence, such as a fingerprint, or 'testimonial' evidence. Farahany describes the following thought experiment:

> A woman is murdered in her home by a masked man wielding a hammer – an act captured on videotape – but first she's able to deliver a blow to his head with the tool. After that counterattack, an accomplice of the man spurs his companion to kill the woman by yelling, 'Let's go!' The police (correctly) suspect that the killer was the woman's husband.[407]

Carrying out brain scans on the husband could then help determine several key facts:

– Did the alleged killer suffer brain damage of the sort a hammer blow might cause?
– What were his automatic and physiological responses to photographs of his wife – disdain and loathing? Love and sadness?
– Could the suspect recall the 'Let's go' urging?

Within the current framework of brain scan technology, it may be possible to accept that all of the scans undertaken on the husband should be permissible in court, which could then be regarded as more intrusive than a blood sample. To respond to such a scenario, Farahany proposes a new classification of information, which would capture the types of thought-data being discussed. Moving along a spectrum from the less to the more protected, her proposed categories are:

– identifying information;
– automatic information (produced by the brain or body without effort or conscious thought);
– information that has been memorised; and
– uttered information (including information uttered only in the mind).[408]

Recognising the limitations of these categories, Farahany acknowledges that the gap between how courts treat automatic information and people's moral intuitions is problematic, but argues that the categories can be a tool to expose that gap. Her intention is to try to reconsider how to approach these questions, with the aim of establishing a framework that will give rise to a robust democratic debate about how various competing interests can be balanced. The intention is not to establish categorical results. Instead, Farahany indicates: 'Truthfully, there are things that fall in between, and a better thing to do is to describe the levels of in-betweenness than to inappropriately and with great difficulty assign them to one category or another.'[409]

One example of such a difficulty is when a person gives appropriate consent for parts of his or her brain functions to be examined, without realising that it may be impossible to set limits on what is in fact being read. Thus, he or she may misunderstand, or not realise, what is to be uncovered and what he or she may be giving up.

Because of such concerns (amongst other reasons), the U.S. bioethicist Paul Root Wolpe is not convinced that nonclinical brain scans are ethically appropriate. He believes, instead, that the skull should represent 'an absolute zone of privacy'. In this regard, he mentions the French philosopher Jean-Paul Sartre (1905–80), who suggested that the ultimate power, or right of a person, is to say 'No'. Wolpe observes: 'What happens if that right is taken away – if I say "No" and they strap me down and get the information anyway? I want to say the state never has a right to use those technologies.'[410]

But it should always be remembered, in this context, that investigators may already have personal information, such as physical evidence, which can be far more 'personal' than thoughts. For example, many individuals would probably expect greater privacy relating to the information found in their blood than in the content of their memories or other utterances on a variety of matters.[411]

Privacy and Surveillance

Mindful of the scope of developments in neurotechnologies, any understanding and appreciation of the concept of privacy in the future is still up for debate. In this respect, the U.S. journalist and entrepreneur Zoltan Istvan, who ran for U.S. President in 2016 for the Transhumanist Party, indicated:

> Privacy is a relatively new concept in history, and while it might have served the wealthy for a few thousand years, it's not a long term phenomenon. Machine intelligence doesn't need to be so disconnected. It will discard with privacy. You're seeing that already with how much tech is making people's lives so much less private. Transparency will create a society of trust, openness, liberty, and most importantly, safety.

He added that:

> I think life and evolution will probably take transparency all the way – where everything is known to everyone all the time. Some call this a mind hive. But understand, we won't be human anymore. We'll be far more machine, driven by logic and functionality.[412]

Similarly, commenting on the future, Susan Greenfield predicts that the term 'privacy' will increasingly become arcane and a word that only very old people will occasionally use. Everything will then be public.[413] She suggests: 'We would no longer have private thoughts; rather, we would effectively be part of a larger network, a mere node in a thinking, conscious system that goes way beyond an individual mind.'[414] Greenfield also predicts that future persons may be 'most at home networked into the large, passive collective and therefore do not resent being scrutinized by others. It's more as though they were part of you in any case – a kind of collective self'.[415]

Even at present, in an age where privacy is maybe seen as less important than before, such as with the use of networking sites, it is difficult to predict what the future will hold. Moreover, while a person may accept to be on a networking site, the consequences of such a free decision may not always be well understood. In addition, O'Brolchain and Gordijn suggest that some developments may be on their way, in that: 'The popularity of social networking sites such as Facebook might provide a clue as to how . . . [neuronal interfaces] may be used in the future. Rather than simply sharing photos, videos, and comments, people may in the future choose to share, via . . . [neuronal interface] connections, emotional states and experiences directly.'[416]

Interestingly, research indicates that younger people are usually less concerned with their privacy than older persons and are more willing to share information online.[417] Why this is the case remains to be examined, but some may be less aware of the risks involved. For example, if young persons provide information about themselves on the Internet, it is possible that when they grow up and seek employment, this information could become available to others, such as prospective employers. Social media sites may also combine work and social identities within the same online space, leading to information being transferred from one sphere to another.[418]

The American author Dave Eggers discusses some of the possible future challenges to privacy in his 2013 novel *The Circle*.[419] A society is represented in which anyone who is not linked to the cybernetwork web is considered to be an outcast and no longer part of the embrace of humanity. Privacy and individuality are seen as something negative – as something to be suppressed – and as inappropriate. The only hope of acceptance is to belong to this Circle of communion and unity, while anyone who rejects the technology is ostracised: 'You reject the groups, the people, the listeners out there who want to connect, to empathize and embrace, and disaster is imminent.'[420] What matters is to be accepted into the mass of the millions – to do like them, to be supported by them, to submit to them, to be subsumed by them, to be seen by them and to be known by them.

The aim of the Circle is 'Completion', when everybody knows everything about everybody else and when privacy ceases to exist. The open Circle is then closed. Circle membership would subsequently become mandatory – where all life is channelled through the network. Everything will be permanently recorded, tracked, logged and analysed.

Interestingly, this Circle also reflects to some extent the Panopticon, which was proposed by the English philosopher Jeremy Bentham (1748–47). This is an institutional building and system of control designed to enable all (in Greek *pan*) residents to be seen (in Greek *opticon*) by a single observer, without them knowing whether they are being watched. However, the name also refers to Greek mythology, where Panoptes was a giant with a hundred eyes. In such an institution, because residents do not know when they are being observed, they are encouraged to behave as if they are being watched all the time. In other words, the Panopticon effectively coerces the residents to continuously control their behaviour. Such a system was taken up by the French philosopher Michel Foucault (1926–84) as an image of modern disciplinary societies and their pervasive tendencies to want to know and observe everything in order to control.[421]

In this regard, the power relationships arising from structures such as the Panopticon result from an imbalance in privacy and the information or knowledge available between those who are being watched and those who are doing the watching in their secret and often inaccessible bases. Such an imbalance may even occur with very few observers who protect their privacy from all others. This is because a controlling power difference or discrepancy exists between these two groups, which is one of the real ethical challenges in such constructions.

The Panopticon can also be seen as a symbol of modern disciplinary power of domination, but where no chains are necessary. The mere possibility of being watched is what disciplines society into following the rules and expectations. As such, it may be suggested that certain technological developments are already encouraging panoptic observation and control. For instance, because users of social media may be aware that they are being permanently monitored, this may force them to behave in a manner that conforms to the norm and expectations. Indeed, if everything is known about everyone, this may encourage all members of a modern society to obey the rules and behave themselves. They all know that they are being watched by each other and as long as they are not doing anything wrong, they are safe. In this respect, Istvan explains:

> [B]rain-to-machine interfaces will likely eventually lead to the hive mind, where everyone can know each other's precise whereabouts and thoughts at all times, because we will all be connected to each other through the cloud. Privacy, broadly thought of as essential to a democratic society, might disappear.

He adds that:

> And I'm hopeful it will, if disappearing privacy trends continue their trajectory, and if technology continues to connect us omnipresently (remember the hive mind?). We will eventually come to a moment in which all communications and movements are public by default . . . We are approaching an era

> where the benefits of a society that is far more open and less private will lead to a safer, diverse, more empathetic world. We should be cautious, but not afraid.[422]

But reality may be more complex and it is recognised that regulations governing the possession of digital information are very different from those of standard offline possession.[423] Once an image has been posted online, it may be retained by the website (depending on its terms and conditions) or others could reproduce, share, adapt and use it in ways that may be troubling to the original owner.[424] Since it is extremely difficult to permanently delete an online personal history, individuals may need to be very careful when sharing personal information online.[425]

A further challenge is the way in which persons are increasingly encouraged to disclose information about themselves through incentives such as access to services like social network sites or free WiFi. This happens because a financial value exists from the exploiting of customer data.[426]

Even individuals who do not choose to have an online presence may be identified through photos of themselves that are uploaded.[427] This also means that individuals may no longer be the primary creators of their own online identities, which may have implications for their offline identities.[428]

Farahany believes that advances in neuroscience represent a challenge to the way in which society has come to understand privacy. She notes: 'We have this idea of privacy that includes the space around our thoughts, which we only share with people we want to . . . Neuroscience shows that what we thought of as this zone of privacy can be breached.'[429] But social media may also facilitate connections between like-minded individuals creating niche communities of interest, which could be benign or malign,[430] while reinforcing existing behaviours, normalising minority identities and broadening choices.[431]

To the extent to which matters of privacy are being discussed, the corresponding issue of surveillance can also be raised. This has generally been defined as recording or storing information about a person's movements and activities, and then processing this information in some way. In this respect, privacy is only impinged if a person is not aware or has not assented to being surveyed.

The Right to Privacy

A right to privacy generally includes the right to not be exposed to unlawful and unethical surveillance by authorities and private enterprises. The UN's Universal Declaration of Human Rights indicates in Article 12 that:

> No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation. Everyone has the right to the protection of the law against such interference or attacks.

Similarly, the Council of Europe Convention for the Protection of Human Rights and Fundamental Freedoms indicates in Article 8 ('Right to respect for private and family life'):

> 1. Everyone has the right to respect for his private and family life, his home and his correspondence.
> 2. There shall be no interference by a public authority with the exercise of this right except such as is in accordance with the law and is necessary in a democratic society in the interests of national security, public safety or the economic wellbeing of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others.

Therefore, privacy should be defended, because it protects the dignity and integrity of the whole person and, in the context of neurotechnology, the right to mental privacy guards the information from a person's mind from unauthorised collection, storage, use or even deletion.[432] Such a right is important when persons may unconsciously be surrendering parts of themselves to others whom they do not know and have no way of knowing. This is one of the reasons why a right to be forgotten in EU law is seen as being crucial. This is a perceived right for individuals to determine the development of their lives in an autonomous way, without experiencing discrimination as a consequence of a specific past action.

In this context, Ienca and Andorno argue that 'current privacy and data protection rights are insufficient to cope with the emerging neurotechnological scenarios. Consequently, we suggest the formal recognition of a right to mental privacy, which aims to protect any bit or set of brain information about an individual recorded by a neurodevice and shared across the digital ecosystem'. They indicate that this right should protect not only neuronal information as data, but also the sources of such information, including whether it is obtained from a person when he or she was conscious.[433]

Such rights to privacy may mean that special software, enabling anonymous use of neuronal interface systems, may need to be developed for:

- circumventing censorship;
- anonymous activism and journalism;
- undercover online surveillance;
- protection from criminals;

- anonymous peer-to-peer file sharing; and
- whistleblowing.

However, it is worth recognising that such anonymity can also be used for negative purposes, for example, in criminal markets, such as in the selling and buying of illegal drugs, the sharing of indecent images of children, and for terrorism. This means that if neuronal interfaces continue to be developed and become ever more present in society, a corresponding risk assessment of potential threats to individual privacy and confidentiality may be required. For example, with the emergence of mass data collections, such as with 'Big Data' sets obtained through social media, the 'Internet of Things' and other devices or settings, new threats to private life may increase.[434] This may imply that data protection principles and data protection laws may need to be revised and improved in order to reflect life in a digital and interconnected world.[435]

In other words, according to Ienca and Andorno, a right to brain privacy should 'protect people against illegitimate access to their brain information and to prevent the indiscriminate leakage of brain data across the infosphere'.[436]

It should finally be noted, however, that in an Edenic society where nobody is ever malevolent to anyone else, a person may not need to hide his or her thoughts through the means of privacy. But such a society, unfortunately, does not exist. This means that a right to privacy will always remain necessary for persons to protect themselves from the controlling power of others.

Notes

1. Parliamentary Assembly of the Council of Europe, *Technological Convergence*, para 2.
2. British Medical Association, *Boosting Your Brainpower*, 3.
3. Ibid., 16–20.
4. Ibid.
5. Ibid.
6. Ibid.
7. Ibid.
8. Ibid., 21–22.
9. Ibid.
10. Here, many of the arguments are similar to those relating to equality of access to eugenics. See MacKellar and Bechtel (eds), *The Ethics of the New Eugenics*, 146–48.
11. A fuller examination of societal inequality should include a substantial discussion on poverty as well as what it is, how it happens and how it may be overcome. Indeed, poverty is a complex phenomenon, encompassing financial, relational and emotional shortfalls. Thus, a more equal distribution of financial resources would be insufficient to counteract poverty. See, for example, Lister, *Poverty*, 36.
12. Anderson, *Feed*.

13. Green, *Babies by Design*, 147–53.
14. Nuffield Council on Bioethics,*Genetics and Human Behaviour*, 153–54.
15. Forster, 'The Machine Stops'.
16. Brandon, 'The Medium is the Message', 2.
17. Fredette et al., 'The Promise and Peril of Hyperconnectivity'.
18. Office for National Statistics, *Internet Access*.
19. Biggs, 'Emerging Issues'.
20. Hulme, *Life Support*.
21. Eynon and Geniets, *On the Periphery?*
22. BBC News, 'S Korean Dies after Games Session'.
23. Lee, 'South Korea Pulls Plug'.
24. Gorlick, 'Media Multitaskers Pay Mental Price'; Ophir, Nass and Wagner. 2009. 'Cognitive Control in Media Multitaskers'.
25. Gorlick, 'Media Multitaskers Pay Mental Price'.
26. Ibid.
27. Foresight Future Identities, *Final Project Report*, 22–24.
28. De Castella, 'Could Work Emails Be Banned after 6pm?'
29. Ibid.
30. It may even become such a significant part of life that three kinds of death may, at present, exist: cardiac death, brain death and disconnection from the network. See Mattei, 'Le corps sera-t-il encore humain?', 78.
31. Berg, 'Will Google Glasses Make Us Cyborgs?'
32. Blair, 'Mind Healing'.
33. Dade, 'Transnationalism, Foreign Assistance, Domestic Communities'; Vertovec, 'Trends and Impacts of Migrant Transnationalism'.
34. Bourn, 'Young People, Identity and Living in a Global Society'.
35. Gutierrez, Vexo and Thalmann, *Stepping into Virtual Reality*.
36. Bainbridge, *Online Multiplayer Games*.
37. Clark, 'Second Life Creator Linden Lab Downsizes'.
38. Castronova, *Synthetic Worlds*.
39. Wagner, 'Second Life CEO Looks to the Future'.
40. Clark, 'Second Life Creator Linden Lab Downsizes'.
41. Heim, *The Metaphysics of Virtual Reality*, 83.
42. Ellison, *Social Media and Identity*.
43. Dutton and Blank, 'Next Generation Users'.
44. Miller, *What is the Relationship between Identities?*
45. Foresight Future Identities, *Final Project Report*, 27–28.
46. Miller, *What is the Relationship between Identities?*
47. Harb, 'Arab Revolutions'.
48. 'Are We Becoming Cyborgs?'
49. Bocquelet et al., 'Ethical Reflections on Brain-Computer Interfaces', 261–88.
50. Greenfield, *Tomorrow's People*, 43.
51. EUCogIII Project Final Report, '3rd European Network'.
52. Ibid.
53. Luber and Lisanby, 'Enhancement of Human Cognitive Performance', 961, quoted in Braude, 'Enhancing Cognition in the "Brain Nation"', 137.
54. Chan and Harris, 'Cognitive Regeneration or Enhancement'; Greely et al., 'Towards Responsible Use'; Foresight Mental Capital and Wellbeing Project, *Final Project Report*.
55. Hamilton, Messing and Chatterjee, 'Rethinking the Thinking Cap'.

56. Farah et al., 'Neurocognitive Enhancement', 422. However, this might be considered as treatment if it is designed to alleviate the effects of recognised health impairments such as post-traumatic stress disorder.
57. Presidential Commission of the Study of Bioethical Issues, 'Gray Matters', vol. 2, 40.
58. Kaufman, *IQ Testing 101*.
59. This corresponds to the regulations in Opinion No. 20 of the European Group on Ethics (EGE) in Science and New Technologies to the European Commission: Secretariat of the EGE, *The Ethical Aspects of Information and Communication Technology Implants in the Human Body: Opinion No. 20*, 16 March 2005, 33–35.
60. Locke, *An Essay Concerning Human Understanding*, II, XXVII, 9.
61. Ibid.
62. The inability to distinguish useful from meaningless information is believed to be one of the features of autism.
63. Lagali, Corcoran, and Picketts, 'Hippocampus Development and Function'.
64. Graham-Rowe, 'World's First Brain Prosthesis Revealed'; Lagali, Corcoran, and Picketts, 'Hippocampus Development and Function'.
65. Lipsman and Glannon, 'Brain, Mind and Machine'.
66. Nsanze, 'ICT Implants in the Human Body', 145; Erden, 'Neural Implants'.
67. Baard, 'Guilt-Free Soldier'; Spezio, 'Human or Vulcan?', 146.
68. See DARPA, Reorganization and Plasticity to Accelerate Injury Recovery (REPAIR).
69. Spezio, 'Human or Vulcan?', 147.
70. Shachtman, 'Darpa Chief Speaks'.
71. Harlow, 'Meet the Cyborgs'.
72. Kurzweil, *How to Build a Mind*, 246.
73. Spezio, 'Human or Vulcan?', 146.
74. Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 61.
75. Presidential Commission of the Study of Bioethical Issues, 'Gray Matters', vol. 2, 36.
76. Kurzweil, *The Singularity is Near*, 23.
77. Ibid., 9.
78. Ibid., 7.
79. Agar, *Humanity's End*, 35.
80. Kurzweil, *The Singularity is Near*, 9, 136.
81. Agar, *Humanity's End*, 7.
82. Kurzweil, *The Singularity is Near*, 486.
83. Ibid., 29.
84. Greenfield, *Tomorrow's People*, 46.
85. Singer, 'A Determinist View of Brain, Mind and Consciousness', 41–48.
86. Frith and Frith, 'The Social Brain'.
87. Singer, 'A Determinist View of Brain, Mind and Consciousness', 41–48.
88. Rappaport, 'The Neuroscientific Foundations of Free Will', 3–23.
89. Presidential Commission of the Study of Bioethical Issues, *Gray Matters*, vol. 2, 43.
90. Jotterand, 'Moral Enhancement', 48.
91. Lipsman and Glannon, 'Brain, Mind and Machine'.
92. Damasio, *Self Comes to Mind*; Spence, *The Actor's Brain*.
93. Singer, 'A Determinist View of Brain, Mind and Consciousness', 41–48.
94. Walter, *Neurophilosophy of Free Will*; Meynen, 'Free Will and Mental Disorder'.
95. Kane, 'Rethinking Free Will', 389.
96. Kane, *The Significance of Free Will*. As a libertarian, Kane believes that free will is incompatible with causal determinism.

97. Mele, *Springs of Action*. See also Mele, *Motivation and Agency*.
98. Fischer and Ravizza, *Responsibility and Control*; Meynen, 'Free Will and Mental Disorder'; Lipsman and Glannon, 'Brain, Mind and Machine'.
99. Blank, *Intervention in the Brain*, 260.
100. Smith, 'Neuroscience vs Philosophy'.
101. Jotterand, 'Moral Enhancement', 45.
102. Singer, 'A Determinist View of Brain, Mind and Consciousness', 41–48.
103. Ibid.
104. Ibid.
105. Crick, *The Astonishing Hypothesis*, 3.
106. Miles, '"Irresponsible and a Disservice"'.
107. Vohs and Schooler, 'The Value of Believing in Free Will'.
108. Libet et al., 'Time of Conscious Intention'.
109. Electroencephalography (EEG) is the recording of electrical activity through the scalp. EEG measures voltage fluctuations using multiple electrodes placed on the scalp
110. Soon et al., 'Unconscious Determinants of Free Decisions in the Human Brain'.
111. For example, in a series of experiments, subjects were primed with certain stereotypes or with people associated with those stereotypes, whereby it was found that they tended to display behaviour consistent with the stereotype. Thus, subjects primed with rudeness were later more interruptive with the experimenter, while subjects primed with the concept of the elderly when doing a simple task later walked more slowly when leaving the experiment.
112. Wegner, *The Illusion of Conscious Will.*
113. See, for example, Libet et al., 'Time of Conscious Intention'; Haggard, 'Human Volition'; Moser et al., 'Coordination in Brain Systems', 193–214; Soon et al., 'Unconscious Determinants of Free Decisions in the Human Brain'.
114. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 75.
115. Planck, *Where is Science Going?*, 201.
116. Cheshire, 'The Origami Brain'.
117. Christen and Müller, 'Effects of Brain Lesions on Moral Agency'.
118. Levy, *Consciousness and Moral Responsibility*.
119. Blank, *Intervention in the Brain*, 131.
120. Jotterand and Giordano, 'Transcranial Magnetic Stimulation', 476–85.
121. Persson and Savulescu, *Unfit for the Future*.
122. Plato, *Timaeus*, (360 B.C.E), translated by B. Jowett, Provided by the Internet Classics Archive, http://classics.mit.edu/.
123. Jotterand, 'Moral Enhancement', 44–45.
124. Ibid., 43–49.
125. DeGrazia, 'Moral Enhancement'; Jotterand, 'Moral Enhancement', 44.
126. Persson and Savulescu, 'The Perils of Cognitive Enhancement'.
127. Jotterand, 'Moral Enhancement', 52–53.
128. De Jong, van Keulen and Quast (eds), *Van Vergeetpil tot robotpak*; Academy of Medical Sciences et al. 2012. *Human Enhancement and the Future of Work.*
129. Goebel, 'Beïnvloeding van hersenactiviteit met behulp van fMRI-neurofeedback en TMS', 59–64; Denys, 'Kansen en risico's van diepe hersenstimulatie', 47–51.
130. Chan and Harris, 'Neuroethics', 82–83.
131. De Ridder et al., 'Moral Dysfunction and Potential Treatments', 155–83; Shook, 'Neuroethics and the Possible Types of Moral Enhancement'; Persson and Savulescu, *Unfit for the Future*.

132. Dubljević and Racine, 'Moral Enhancement Meets Normative and Empirical Reality', 338.
133. Strand and Kaiser, 'Report on Ethical Issues', 36–37.
134. Cheshire, 'Ethical Implications of Transcranial Magnetic Stimulation for Personal Identity', 72.
135. Schneider and Velmans, 'Introduction'.
136. Frackowiak et al. (eds), 'The Neural Correlates of Consciousness', 269.
137. Sutherland, 'Consciousness'.
138. Singer, 'Consciousness from a Neurobiological Perspective', 242.
139. Rose, 'Preface', 14–15.
140. Güzeldere, Block and Flanagan, *The Nature of Consciousness*, 1–67.
141. Fins, Schiff and Foley, 'Late Recovery'.
142. Zeman, 'Consciousness'.
143. Greenfield, *Tomorrow's People*, 213.
144. Ibid., 214.
145. Ibid., 215.
146. The Australian philosopher David Chalmers explained that the 'hard problem' of consciousness arises because a complete objective interrogation of the brain cannot be used to understand the subjective experiences of the person to whom the brain belongs. In other words, all scientific measurements will only describe what happens from the outside and cannot be used to understand what is happening on the inside. See Chalmers, 'Facing up to the Problem of Consciousness'.
147. Dawkins, *The Selfish Gene*, 59.
148. Greenfield, *Tomorrow's People*, 209–10.
149. Hobbes, *Leviathan*, Chapter XIII.
150. Stuart Mill, 'Autobiography', 94.
151. Nozick, *Anarchy, State, and Utopia*.
152. Geraci, 'Video Games and the Transhuman Inclination', 740.
153. Cline, *Ready Player One*.
154. Inglis, 'Crafting the Endless Cosmos of No Man's Sky'.
155. Heim, *The Metaphysics of Virtual Reality*, 136.
156. Ibid., 137.
157. Waters, *From Human to Posthuman*, 56–57.
158. Ibid., 57.
159. Ibid.
160. BBC News, 'S Korean Dies after Games Session'.
161. American Psychological Association, 'Technical Report on the Review of the Violent Video Game Literature'.
162. Von Radowitz, 'Study Finds that Violent Video Games May Be Linked to Aggressive Behaviour'.
163. American Psychological Association, 'Technical Report on the Review of the Violent Video Game Literature'. However, because of such perceived risks, in 2009,Germany's sixteen regional interior ministers asked the Federal Parliament to ban the creation and distribution of games involving violent acts against human or human-like characters. See Aron, 'Online Petition Stalls Plan'.
164. Vytal and Hamann, 'Neuroimaging Support for Discrete Neural Correlates of Basic Emotions'.
165. Kass, 'Ageless Bodies, Happy Souls'.
166. Harris, *Enhancing Evolution*, Chapter 7; Chan and Harris, 'Neuroethics', 82.

167. Erden, 'Neural Implants'; Soekadar, Haagen and Birbaumer, 'Brain–Computer Interfaces (BCI)', 229–52.
168. Philpot et al., 'Barriers to the Use of Electroconvulsive Therapy in the Elderly'.
169. Reardon, 'AI-Controlled Brain Implants'.
170. Ibid.
171. Harlow, 'Recovery from the Passage of an Iron Bar through the Head'.
172. Macmillan, *An Odd Kind of Fame*.
173. Burns and Swerdlow, 'Right Orbitofrontal Tumor'.
174. Strand and Kaiser, 'Report on Ethical Issues', 4.
175. Ibid., 22.
176. See, for example, Schermer, 'Ethical Issues in Deep Brain Stimulation'; Schüpbach et al., 'Neurosurgery in Parkinson Disease'.
177. Schneider et al., 'Deep Brain Stimulation'; Demetriades, Rickards and Cavanna, 'Impulse Control Disorders'.
178. Strand and Kaiser, 'Report on Ethical Issues', 22.
179. Jotterand and Giordano, 'Transcranial Magnetic Stimulation', 476–85.
180. Cheshire, 'Ethical Implications', 76.
181. British Medical Association, *Boosting Your Brainpower*, 25–26.
182. Ibid., 26.
183. Christen and Müller, 'Effects of Brain Lesions on Moral Agency'.
184. Erikson, *Identity, Youth and Crisis*.
185. Cheshire, 'Ethical Implications of Transcranial Magnetic Stimulation for Personal Identity'.
186. Kroger, *Identity Development*.
187. Miller, *What is the Relationship between Identities?*
188. Kroger, *Identity Development*.
189. Foresight Future Identities, *Final Project Report*, 9–10.
190. For further discussion, see, for example, Schechtman, *The Constitution of Selves*; Schermer, 'Ethical Issues in Deep Brain Stimulation'; Foresight Future Identities, *Final Project Report*, 9–10; de Grazia,*Creation Ethics*, 70–73.
191. This reflects an 'animalism' perspective that was coined by Paul F. Snowdon. See Snowdon, 'Personal Identity and Brain Transplants', 109–26. For a discussion, see Olson, 'An Argument for Animalism', 318–34. See also Snowdon, *Persons, Animals, Ourselves*.
192. Even conjoined twins can be considered as distinct if they each experience their own specific identity.
193. Glannon, 'Identity, Prudential Concern, and Extended Lives', 269.
194. Mathews, 'Deep Brain Stimulation'.
195. See, for example, Mackenzie and Stoljar, 'Introduction'. For a discussion on relational autonomy in the context of respecting the interests of those with dementia, see Nuffield Council on Bioethics, *Dementia*, para 2.53.
196. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 74.
197. This is not to suggest that memory loss and its effect on self-perception make those with dementia any less deserving of respect as persons. The Nuffield Council on Bioethics' previous report on dementia explores these questions, emphasising the importance of making sure that those living with this condition are not stigmatised and that it is possible to live a fulfilling life with dementia. See Nuffield Council on Bioethics, *Dementia*, 30. See also, for example, National Institute for Health and Care, *Dementia*, 4; Dworkin, *Life's Dominion*, 224–25; Nuffield Council on Bioethics, *Novel Neurotechnologies*, 74.

198. Erden, 'Neural Implants'.
199. Waters, *From Human to Posthuman*, 53.
200. Ienca and Andorno, 'Towards New Human Rights', 20.
201. Ibid.
202. Ibid., 24.
203. Nsanze, 'ICT Implants in the Human Body'.
204. Foresight Future Identities, *Final Project Report*, 25–27.
205. Couldry, *Media, Society, World*.
206. Madianou and Miller, 'Polymedia'.
207. Foresight Future Identities, *Final Project Report*, 25–27.
208. Ibid., 22–24.
209. Turkle, *Alone Together*.
210. Miller, *What is the Relationship between Identities?*
211. Briggs, *Will an Increasing Element of Our Identity Be 'Devolved' to Machines?*
212. Miller, *What is the Relationship between Identities?*
213. Brooks and Nicholas, *Virtual Humanity*, 105.
214. WikiHow, 'How to Fake Your Identity Online'.
215. Ellison, *Social Media and Identity*.
216. McCaskill, 'Filing Reveals 83 Million Fake Facebook Accounts'.
217. Jong, 'Why the Number of People Creating Fake Accounts and Using Second Identity on Facebook are Increasing'; Krotoski, 'Online Identity'.
218. Burnett, Consalvo and Ess, *The Handbook of Internet Studies*,.
219. Foresight Future Identities,*Final Project Report*, 25–27.
220. 'Cyber Cheats Married . . . to Each Other'.
221. See the 2009 American science-fiction film *Surrogates*, directed by Jonathan Mostow and starring Bruce Willis.
222. Ginsburg, 'Disability in the Digital Age', 91–126.
223. Williams et al., *Experience and Expectation of Disabled People*.
224. Ouellette, 'My So-Called Second Life'; Miller, *What is the Relationship between Identities?*
225. Ward, 'Web Porn'.
226. Graham, *Representations of the Post/Human*, 2, quoted in Messer, *Respecting Life*, 133.
227. Graham, *Representations of the Post/Human*, 11, quoted in Messer, *Respecting Life*, 133–34.
228. Paré, *On Monsters and Marvels*. However, it should also be noted that for the early modern scientist and philosopher Francis Bacon, monsters were to be treated as natural phenomena whose study could yield insights into natural processes. See Bacon, *The New Organon*, 2.29.
229. Graham, *Representations of the Post/Human*, 13, quoted in Messer, *Respecting Life*, 134.
230. Graham, *Representations of the Post/Human*, 50, quoted in Messer, *Respecting Life*, 135.
231. E. Graham, *Representations of the Post/Human*, Chapter 3, mentioned in Messer, *Respecting Life*, 135.
232. Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 15–16. Clear guidance as to the importance of dignity can also be found in the UN's 1948 Universal Declaration of Human Rights.
233. Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 15–16.
234. Ibid.
235. Hildt, 'Brain–Computer Interaction'; Bell, Mathieu and Racine, 'Preparing the Ethical Future of Deep Brain Stimulation'; Giordano and Gordijn (eds), *Scientific and Philosophical Perspectives in Neuroethics*.

236. Strand and Kaiser, 'Report on Ethical Issues', 35.
237. Brandon, 'The Medium is the Message', 4.
238. See Offray de la Mettrie, *Machine Man and Other Writings*, 31.
239. Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 31.
240. Moor, 'Becoming a Cyborg', 43–44.
241. De Preester and Tsakiris, 'Body-Extension versus Body-Incorporation'.
242. Cole-Turner, 'Introduction', 7.
243. Ibid., 7–8.
244. Clark, 'Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence', 34.
245. Moravec, *Mind Children*, 4.
246. Joslyn, Turchin and Heylighen, 'Cybernetic Immortality'.
247. Chan and Harris, 'Neuroethics', 83–84.
248. Kurzweil, *The Singularity is Near*, 30.
249. Agar, *Humanity's End*, 53.
250. Kurzweil, *The Singularity is Near*, 9.
251. Chan and Harris, 'Neuroethics', 83–84.
252. It is likely that Teilhard de Chardin influenced the terminology of Julian Huxley in coining the term 'transhumanism' in a short chapter published six years later, as the two were close friends. See Huxley, 'Transhumanism'; Grumett, 'Transformation', 38.
253. Harrison and Wolyniak, 'The History of "Transhumanism"'.
254. Huxley, 'Transhumanism', 13–17.
255. Tirosh-Samuelson, 'Science and Human Betterment', 59.
256. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'; McNamee and Edwards, 'Transhumanism, Medical Technology and Slippery Slopes'
257. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
258. Agar, *Humanity's End*, 29.
259. Wolfe, *Limbo*.
260. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
261. Kurzweil, *The Singularity is Near*, 374.
262. Ibid., 310.
263. Agar, *Humanity's End*, 55.
264. Huxley, *Religion Without Revelation*.
265. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
266. Waters, *From Human to Posthuman*, 78.
267. Savulescu, 'The Human Prejudice', 214. Cf. World Transhumanist Association, 'Transhumanist FAQ'.
268. Hayles, *How We Became Posthuman*, 3.
269. Ibid., 2–3.
270. Ibid., 3–4.
271. Gibson, *Neuromancer*, 16; Hayles, *How We Became Posthuman*, 5.
272. Geraci, 'There and Back Again'.
273. Kurzweil, *The Age of Spiritual Machines*; Kurzweil, *The Singularity is Near*
274. Moravec, *Mind Children*; Moravec, *Robot*.
275. De Garis, *The Artilect War*; de Garis, *Artificial Brains*.
276. Geraci, 'Apocalyptic AI', 149.
277. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
278. Moravec, *Mind Children*.

279. Moravec, *Robot*, 11.
280. Ibid., 146.
281. Kurzweil, *The Singularity is Near*, 9.
282. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
283. Moor, *Enhancing Me*, 42.
284. Geraci, 'Apocalyptic AI'.
285. Moravec, *Mind Children*, 116.
286. Moravec, *Robot*, 163.
287. Ibid., 167.
288. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
289. Kurzweil, *The Singularity is Near*, 9.
290. Bainbridge, 'Religion for a Galactic Civilization', 187–201.
291. Bainbridge, 'Trajectories to the Heavens', 5.
292. Ibid., 3.
293. Herzfeld, *In Our Image*, 73.
294. Bainbridge, 'Trajectories to the Heavens', 30.
295. Hayles, *How We Became Posthuman*.
296. Waters, *From Human to Posthuman*, 77–78.
297. Ibid., 58–59.
298. Hayles, *How We Became Posthuman*.
299. Waters, *From Human to Posthuman*, 78.
300. Pepperell, *The Post-human Condition*, 34.
301. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith'.
302. Waters, *From Human to Posthuman*, 78.
303. Wainwright, *For Our Salvation*, 18.
304. Ibid.
305. Kurzweil, *The Singularity is Near*, 324.
306. Kurzweil, *How to Create a Mind*, 276.
307. Kurzweil, *The Singularity is Near*, 235.
308. Locke, *An Essay Concerning Human Understanding*, II, XXVII, 23.
309. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith', 717.
310. Kurzweil, *The Singularity is Near*, 122–25.
311. Ibid., 126–27.
312. Ibid., 125–26.
313. Agar, *Humanity's End*, 39–40.
314. Ibid., 46–47.
315. Ibid., 50.
316. Kurzweil, *The Singularity is Near*, 386.
317. Agar, *Humanity's End*, 36.
318. Ibid., 58.
319. Ibid., 59.
320. Kurzweil, *How to Create a Mind*, 245.
321. Moor, *Enhancing Me*, 58.
322. Shen, 'Whole Human Brain Mapped in 3D'.
323. Moor, *Enhancing Me*, 58; Shen, 'Whole Human Brain Mapped in 3D'. In 2003, the Brain Atlas, comprised of digitalised high-definition structural maps collected from MRI studies of more than 7,000 subjects, was published on the Internet. Retrieved 19 October 2018 from http://www.med.harvard.edu/aanlib/home.html.
324. Shen, 'Whole Human Brain Mapped in 3D'.

325. Moravec, *Mind Children*, 108–10.
326. Ibid., 115–16.
327. Geraci, 'Video Games and the Transhuman Inclination', 737–38.
328. Kurzweil, *The Age of Spiritual Machines*, 33; Kurzweil, *The Singularity is Near*, 7–21; Moravec, *Robot*, 165–67.
329. Geraci, 'Video Games and the Transhuman Inclination', 737–38.
330. Kurzweil, *The Age of Spiritual Machines*, 101–31; Moravec, *Mind Children*, 100–24
331. Waters, *From Human to Posthuman*, 64–65.
332. Heim, *The Metaphysics of Virtual Reality*, 97.
333. Waters, *From Human to Posthuman*, 55.
334. Heim, *The Metaphysics of Virtual Reality*, 99.
335. Waters, *From Human to Posthuman*, 55–56.
336. Ibid., 64–65.
337. Asimov, 'The Last Question'.
338. Turing, 'Computing Machinery and Intelligence'.
339. Moor, *Enhancing Me*, 60–62.
340. There may also be some ethical questions about the possibility of downloading a computer person into the brain of a human biological person.
341. Moor, *Enhancing Me*, 43.
342. Ibid., 45.
343. Tirosh-Samuelson, 'Transhumanism as a Secularist Faith', 725–26.
344. Geraci, 'Video Games and the Transhuman Inclination', 748.
345. Castronova, *Exodus to the Virtual World*, 59.
346. Bainbridge, *The Warcraft Civilization*, 62.
347. Geraci, 'Video Games and the Transhuman Inclination', 737.
348. Rohrer, 'GameDesign Sketchbook'.
349. Geraci, 'Video Games and the Transhuman Inclination', 745.
350. Au, *The Making of Second Life*, 233.
351. Ibid., 232.
352. Guest, *Second Lives*, 273; Geraci, 'Video Games and the Transhuman Inclination', 745–46.
353. Bostrom, 'Ethical Principles in the Creation of Artificial Minds'.
354. Moor, *Enhancing Me*, 58.
355. This novel was a revised and expanded version of Clarke's earlier story *Against the Fall of Night*, but the earlier version did not contain the elements relating to mind uploading.
356. Geraci, *Apocalyptic AI*, 54. Note that although Geraci presents this as the first story to feature mind uploading, he incorrectly gives the publication date as 1953, which is actually the publication date of the novel *Against the Fall of Night*, of which *The City and the Stars* was a revised version. See Tofts, Jonson and Cavallaro (eds), *Prefiguring Cyberculture*, 253; Bainbridge, *Berkshire Encyclopedia*, 438; Dinello, *Technophobia!*, 172.
357. MacKay, *Behind the Eye*, 1–11, 262–66.
358. DIbid.
359. Cheshire, Jr., 'The Sum of All Thought', 139.
360. The reality that uploading memories into new supports would end up creating new persons who may believe that they are the original was used in several film scripts, such as *Moon* (2009), directed by Duncan Jones, and *The 6th Day* (2000), directed by Roger Spottiswoode.
361. If the virtual twin is considered as a kind of clone of the original, then existing legislation relating to the prohibition of reproductive cloning could come into effect.

362. Reid, *Letter to Lord Kames*, quoted in Humphrey, *Seeing Red*, 1.
363. Sutton, 'Transhumanism', 122.
364. Durkheim's idea on the collective consciousness are discussed in Giddens, *Durkheim*.
365. Durkheim, *Sociologie et philosophie*, 79.
366. Teilhard de Chardin, *The Future of Man*, 124–39; Teilhard de Chardin, *The Phenomenon of Man*, 191–212.
367. In this regard, Teilhard de Chardin may have been inspired by the telecommunications super-organism of H.G. Wells, characterised as the 'word brain'. See Rayward, 'H.G. Wells's Idea of a World Brain'.
368. Burdett, 'Contextualizing a Christian Perspective', 31.
369. Moravec, *Robot*, 201–2.
370. Teilhard de Chardin, *The Future of Man*; Teilhard de Chardin, *The Phenomenon of Man*.
371. Teilhard de Chardin, *The Future of Man*, 128.
372. Burdett, 'Contextualizing a Christian Perspective', 31–31.
373. Ibid.
374. Teilhard de Chardin, *Activation of Energy*, 380.
375. Teilhard de Chardin, *The Future of Man*, 172–73.
376. De Lubac, *The Religion of Teilhard de Chardin*, 208–16.
377. Greenfield, *Tomorrow's People*, 247.
378. Anderson, 'Argumentation, Symbiosis, Transcendence'.
379. P. Russell, First published in 1983 as *The Global Brain* and published in 1995 as *The Global Brain Awakens: Our Next Evolutionary Leap*.
380. Stock, *Metaman*.
381. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 168.
382. Ibid.
383. This is a sort of Tower of Babel syndrome.
384. Greenfield, *Tomorrow's People*, 213.
385. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 168.
386. Lewis, *The Screwtape Letters*, xi–xii.
387. The Austrian medical doctor and psychotherapist Alfred Adler (1870–1937) incorporated the 'Will to Power' concept into his own understanding of psychology by suggesting that it is an innate driving force behind every human being's behaviours and experiences, which he initially defined as 'striving for superiority', but which he later characterises as a 'striving for perfection. See Adler, *Understanding Human Nature*; Adler, *Social Interest*, 275–76.
388. Nietzsche, *The Will to Power*, s. 636.
389. Westin, 'Privacy and Freedom', mentioned in Ienca and Andorno, 'Towards New Human Rights'.
390. Brandon, 'The Medium is the Message', 3.
391. Presidential Commission of the Study of Bioethical Issues, *Gray Matters*, vol. 2, 90.
392. Chan and Harris, 'Neuroethics', 78–79.
393. Barker, 'Health Care/Medical Treatment', 69.
394. Ibid.
395. Parliamentary Assembly of the Council of Europe, *Technological Convergence*, para 9.
396. Barker, 'Health Care/Medical Treatment', 69.
397. Exceptions might be Brain Computer Interfaces, which record a user's brain signals with respect to an external stimulus or with a change in affective state. This could potentially reveal what it was that attracted the user's attention or could represent

a crude reflection of the user's mood. See, for example, Martinovic et al., 'On the Feasibility of Side-Channel Attacks'.
398. Haxby et al., 'Distributed and Overlapping Representations of Faces and Objects'.
399. Ibid.
400. Shea, 'Watch What You Think'.
401. At least two commercial companies offer such services in the United States.
402. Functional Magnetic Resonance Imaging (fMRI) is a type of specialized MRI scan used to measure the haemodynamic response (change in blood flow) related to neural activity in the brain or spinal cord of humans or other animals. Its advantages include its relatively low invasiveness, absence of radiation exposure and relatively wide availability.
403. Weisberg et al., 'The Seductive Allure of Neuroscience Explanations'. See also British Psychological Society, 'Will Juries Be Seduced by Brain Scans?'.
404. Shea, 'Watch What You Think'.
405. Bizzi et al., *Using Imaging to Identify Deceit*.
406. Shea, 'Watch What You Think'.
407. Ibid.
408. Ibid.
409. Ibid.
410. Ibid.
411. Ibid.
412. DeVoe, 'Transhumanism and Crypto'.
413. Greenfield, *Tomorrow's People*, 42.
414. Ibid., 43.
415. Ibid., 38.
416. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 168.
417. Children and Online Privacy Survey, *The i in Online*.
418. Foresight Future Identities, *Final Project Report*, 27–28.
419. Eggers, *The Circle*.
420. Ibid., 464.
421. Foucault, *Discipline and Punish*.
422. Istvan, 'Liberty Might Be Better Served by Doing away with Privacy'.
423. Odom et al., 'Lost in Translation'.
424. Harvey, *Can Histories of Previous Technological Breakthroughs?*
425. Foresight Future Identities, *Final Project Report*, 27–28.
426. Ibid.
427. Ellison, *Social Media and Identity*.
428. Briggs, *Will an Increasing Element of Our Identity Be 'Devolved' to Machines?*
429. Shea, 'Watch What You Think'.
430. Miller, *What is the Relationship between Identities?*
431. Briggs, *Will an Increasing Element of Our Identity Be 'Devolved' to Machines?*
432. Ienca and Andorno, 'Towards New Human Rights', 24.
433. Ibid., 15.
434. Strand and Kaiser, 'Report on Ethical Issues', 36–37.
435. Barker, 'Health Care/Medical Treatment', 69.
436. Ienca and Andorno, 'Towards New Human Rights', 15.

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Chapter 6

Neuronal Interfaces and Policy

The important anthropological and ethical consequences resulting from the development of direct neuronal interfaces and the associated possibilities for the mind to interact with cyberspace cannot be evaded or ignored. These range from largely theoretical philosophical questions to practical concerns regarding possible inappropriate applications of present and future technologies. As the European Parliament's 2009 Science and Technology Options Assessment's report entitled *Human Enhancement Study* indicated:

> [W]orries arise when one considers who is responsible for one's actions, if these can be incited by technology-induced affective responses. Although there seems to [be] quite a huge gap between such worries and the scientific state of affairs, there are clearly moral worries along these lines that are already topical.[1]

In the use of neuronal interfaces, the medical principle of informed consent becomes a very difficult notion to define, as does the concept of moral responsibility for an action. Who should be held accountable for any resulting damage: the patient, the device or the healthcare professional who implanted it and turned it on?[2]

The European Parliament report concludes: 'Neurophilosophers, neuroethicists, neurosociologists and neurojurists are presented with a challenging case . . . What to think of "the self" if its essential attributes of mood and emotions can be manipulated at will.'[3]

So far, legislation regulating the actions and behaviour of persons has generally been restricted to human persons and is based on human rights and dignity. However, as already noted, with the development of neuronal interfaces, the concept of the 'human' may increasingly become unclear, which may then blur the understanding of inherent human dignity, which is the very foundation of human rights and human legislation. As a result, new national and international legislation may be seen as necessary to address some of the cyberneuroethical challenges presented previously. As Ienca and Andorno indicate: 'In contrast to other biomedical developments, which have already been the subject of standard-setting efforts at the domestic and international level, neurotechnology still largely remains a *terra incognita* for human rights law.'[4] More specifically they argue that new legal systems may have to be prepared to address the challenges that may arise from the emerging neurotechnologies, especially in the context of human rights.[5]

New Cybercrimes

Cybercrimes are usually defined as crimes that involve a computer and a network, and are committed against individuals or groups of individuals with a criminal motive.[6] They also include offences in which individuals seek to illegally access the computers of others (known as hacking). As such, the 'cyber' prefix is used, as in many other settings, in a very general and loose sense.[7]

Nonstate actors as well as individuals can participate in cybercrimes, including espionage, financial theft and other offences that may affect millions of individuals, private businesses and governments.[8] When national governments target and use computers and networks of other governments for both offensive and defensive operations, such as cyberattacks, espionage and sabotage, this is usually defined as cyberwarfare.

Within this context, large amounts of money are invested every year by states, banks, businesses and organisations in seeking to protect themselves from such attacks. In the following sections, however, only cybercrimes that may become relevant to those using neuronal interfaces will be addressed.

Mental Integrity

In the development of a neuro-oriented human rights framework, one of the most important principles that may need to be considered reflects the notion of cognitive liberty. This is presented as a right to mental self-determination, which includes both an individual right to use emerging neurotechnologies and a right to be protected from any coercive and unconsented use of such technologies. Thus cognitive liberty reflects the right for individuals to be able, or to refuse, to change their mental states using neurotechnology.[9]

Such a right to be protected from unauthorised interventions in the brain seeks to address the (already mentioned) risks presented in the Japanese animated science-fiction series *Ghost in the Shell.* In this, computer technology is so advanced that many members of the public have enhanced cyberbrains, allowing their biological brains to interface with various networks. But this high level of inter-connectedness also makes the brain vulnerable to attacks from highly skilled hackers, including those who will hack a person to completely control their will, change their memory and deliberately distort their subjective reality and experience. This means that it may be possible for future WiFi neuronal interfaces to be used by a hacker, or even a certain government, to remotely influence the brains of other persons or their devices in order to seek to subconsciously or even consciously control them or change their way of thinking.[10]

In this regard, Ienca and the Dutch philosopher and psychologist, Pim Haselager, defined the concept of 'malicious brain-hacking' as neurocriminal activities that directly affect neural computation in the users of neurodevices in a similar manner to the way in which computers may be hacked in computer crime.[11] Accordingly, it is not only the users' mental privacy and the protection of their brain information that are at risk, but also their physical and mental integrity. [12] More specifically, Zoltan Istvan explains:

> To me, the biggest need in the future will be cyber security coders, who will create ways to protect people that are basically interfacing directly with the web with their mind. Ultimately, I think we'll have a police force that can carefully and quickly stop cyber crime, including that in our minds. That will be necessary in order for humanity to upload its thoughts to the machine world and feel safe – otherwise, we'll never do it.[13]

On this account, Article 3 of the EU's Charter of Fundamental Rights may be relevant, since this recognises that 'everyone has the right to respect for his or her physical and mental integrity.' Consequently, Ienca and Andorno indicate that for an action to qualify as a threat to mental integrity, it must:

(i) involve the direct access to, and manipulation of, neural signalling;
(ii) be unauthorised – in other words, it must occur in absence of the informed consent of the signal generator;
(iii) result in physical and/or psychological harm.[14]

However, it has been proposed that the right to mental integrity could legally be transgressed in some very specific circumstances. For instance, if moral enhancements can be shown to be safe and effective, then an argument could be made for the compulsory, controlled and temporary violation of this right to mental integrity for some dangerous individuals.[15]

Identity Theft

Because of the amount of personal information now available in cyberspace, cybercrimes involving identity theft are increasingly becoming a problem. Such crimes use the personal information of a victim to exploit the benefits of his or her identity for a whole range of criminal purposes.[16] Moreover, because they use part of an individual's sense of self, victims usually experience the crimes as very disturbing and invasive. Instances of blackmail and extortion may take place, as well, which threaten to reveal personal information or destroy reputations.[17]

In the future, criminals may also be able to use the personal identity of a person as well as his or her private thoughts, ideas or memories for their own benefit. In other words, crimes relating to the very integrity and probity of an individual could develop. Stealing sufficient information could even enable criminals to completely take over their victims' offline or online identities.[18]

This means that society should be ready for such kinds of crimes against persons and organisations that may become possible in cyberspace. New technology may need to be developed against instances, such as mining large datasets as well as cross-referencing a range of personal and other information.[19,20]

But because the distinction between online and offline identities may continue to diminish in the future, a person's identity and privacy may increasingly become difficult to protect. Moreover, if persons spend more and more time in cyberspace, the re-evaluation of the identity of a person in cyberspace may mean that offences to this identity may need to be re-evaluated.

Demonstrating Causality

Usually, in order to identify who is responsible for an outcome, it is important to analyse the causal chain for an action. This means that an individual can be held responsible for a certain outcome if he or she has a causal connection to it, is aware of the eventual result and did not act under compulsion or duress.[21] As O'Brolchain and Gordijn indicate, 'if a person is to be considered morally responsible for a particular event or action, that person must have been able to exert some kind of influence on that event and must have known that in doing so a certain consequence would most likely have ensued'.[22]

Demonstrating such a responsibility, however, may not be easy in the use of neuronal interfaces, since determining who is really in control, and of what, may be unclear or complex. As already noted, with procedures such as neuroimaging, scientists may be able to detect a correlation between a particular behaviour and brain structure or brain activity. But such an association cannot be considered as reliable evidence of causation. For example, if a correlation is shown to exist between brain structure and political conservatism or liberalism,[23] it may be impossible to conclude that certain brain structures cause a particular political disposition. Instead, it may be that certain political views may cause differences in brain structure or that both political beliefs and brain structure were the result of some other cause.[24]

It follows that concepts of causality in neuroscience are not always similar to those that are used in law. If it is proposed that an action is the cause of a certain outcome in a court of law, then it must be proved that this result would not have occurred but for the original action. This means that investigations are required to demonstrate any element of causality.[25] If these showed, for instance, that an injury changed the brain structure, resulting in a change of behaviour, then it may be possible that a causal link existed.

For a person to be guilty of a crime, both an *actus reus* (a wrongful act) and *mens rea* (actual criminal intent or at least a gross and wrongful recklessness as to the consequences of one's actions) is required. Thus, if a person is unconscious and, as a result, is incapable of forming criminal intent, he or she cannot have *mens rea*. Equally, automatism (as in sleepwalking) can be a defence, as can an involuntary action (as in sneezing whilst driving a car). Or again, the state of a person's mind may be such that he or she may nonetheless plead diminished responsibility to lessen his or her culpability for his or her actions.

In the context of cyberneuroethics, however, the logical end point of such a discussion over responsibility may be difficult to fathom. The role of the law raises questions that are more often implicit than explicit concerning the relationship of law, science and society. Accordingly, legislation may only be seen as effective if it reflects societal values and priorities. Perhaps, this may also mean that there should be a limit beyond which a person should not go in law, a point at which the courts say 'this far and no further'.

Such a perspective is important, for instance, in discerning what the attitude of the courts would be if they are ever confronted with the proposition 'it was not me; it was my neurons' or 'it was not me; it was the computer programme'. It also means that whatever scientific evidence is presented, there may be a legal line over which, on policy grounds, a person should simply not go. Otherwise, no one would ever be guilty of any crime, which may not be considered acceptable to the society in which the law was drafted.

How then will cyberneuroethics eventually be reflected in law? In reply, it should perhaps be recognised that because the law tends to develop step by step and, to some extent, is influenced by social values, it may be difficult to see what direction this may take. In addition, any new laws may have some influence on shaping society and for promoting what could be considered as 'normal' behaviour in the future.

Future Cybercrimes

With the continued development of virtual realities and cybercommunities, a new setting is created, which, if no regulations are established, may eventually result in individuals being harmed and responsibilities being blurred. For example, when a soldier is connected to computers through a neuronal interface to control military drones and one of these accidentally bombs the wrong target, questions could be asked as to who should be blamed. Is it the soldier, the neuronal interface connected to the computer or the programmer who designed the system?

At present, the law makes a distinction between human operators and technical systems, while requiring operators to be responsible for these systems. But the situation would change if the operators' cognition was enhanced by a neuronal interface appliance linked to a computer. It would then be difficult to separate the human operator from the system and the concept of responsibility would become unclear.

Of course, some parallels already exist with the use of drugs to control thoughts and behaviour, making persons more efficient and attentive, but the exact nature of the concept of free will and responsibility may have to be reconsidered in many contexts where new neuronal interface systems are used. At the same time, if an ever-increasing amount of information is available about a person's thoughts, it may become possible to examine a person's intentions to commit a crime. This could then be used by law enforcement organisations similar to the 'Precrime' specialised police department in the film *Minority Report*, which apprehends future criminals based on foreknowledge.

But, in a way, this may not be so new, since psychiatrists already find themselves in similar situations when they discover that one of their patients represent a very significant danger to society, though he or she has not yet committed any crimes.

What Is Real and What Is Virtual?

With the development of neuronal interfaces, it is also possible to question whether a crime committed in cyberspace, such as between two *Second Life* avatars, should be considered a crime in real life and to what extent. To a certain degree, the extension of the law's jurisdiction into *Second Life* and other virtual reality settings is already taking place, in that an English court settled a divorce case on the basis of a spouse's adulterous avatar.[26] In other words, this may have happened because what took place in cyberspace affected real physical persons.

But since only real persons can be affected with moral values, at present, this may mean that the way in which cyberspace and its virtual realities affect real human persons is important.[27] For instance, if a person, who exists in real life, sets out to deliberately cause harm or loss to other real persons as a consequence of his or her actions or omissions in cyberspace, then there may be a case for his or her prosecution. What is important is the concept of cause and effect on real persons or organisations.

Moreover, the Parliamentary Assembly of the Council of Europe indicated in 2017 that responsibility and accountability for an act should always lie with a human being, adding:

> References to independent decision making by artificial intelligence systems cannot exempt the creators, owners and managers of these systems from accountability for human rights violations committed with the use of these systems, even in cases where an act causing damage was not directly ordered by a responsible human commander or operator.[28]

A difficulty may also arise if an individual is not considered to be as responsible for a crime in cyberspace as in real life. Indeed, this might have a detrimental effect on the character of the person in real life. He or she may begin to enjoy the feeling of committing a crime without penalty in virtual reality, which may then have repercussions in real life.

In this context, however, it should be remembered that many games, even for children, may involve the killing of one of the players in the imaginary world, though this is not considered to be a significant danger in the real world. In this case, the strong imaginary element may downplay the reality of the destruction, while the rules of the game take into account, right from the beginning and with all the players' knowledge, the fact that some of their avatars may be killed.

Policy Concerns

The philosopher of medicine and medical ethicist Hillel Braude mentioned in 2016 that the former Israeli President Shimon Peres (1923–2016) had come to the conclusion that people 'cannot govern the world without at least understanding how does [sic] the brain govern us', adding that it is '[t]he greatest hope that we shall begin to understand how does [sic] our own brain function, and then we shall not be beggars of the brain, but choosers of its machinery, of its function'.[29]

However, significant concerns have also been expressed, with the American physician and ethicist Christopher Hook indicating:

> Not only will our cybernetic connectedness provide opportunities for others to have access to us. How much more will individuals be subject to those who

> wish to control and influence them? Will we be able to separate out and eliminate images, instructions, or 'thoughts' meant to influence us, both from commercial and governmental sources? How much further will our privacy erode when the last bastion of our privacy, our mind, is open to the cybernetic web? And as a further danger, will there be new types of electronic viruses that can damage out brains as well as the cybernetic equipment we are 'attached' to?[30]

Whether human persons will ever be able to entirely control their own or other people's brains is open for debate. But such proposals may serve to exemplify the extensive questions already being raised within cyberneuroethics. The important consequences of developing a direct neuronal interface with an appliance, such as a computer, and the resulting possibilities for the mind to interface with cyberspace cannot be sidestepped. These range from largely theoretical anthropological and philosophical questions to practical concerns regarding possible inappropriate applications of present and future technologies.

The brain of a person is indeed a very sensitive organ and any use of a neuronal interface may have consequences for the individual and the way in which he or she interacts with others. Robert Blank indicates that: 'As the center of personal autonomy and identity, the brain enjoys special status, and modifying it even slightly raises concerns of manipulation.'[31] Consequently, because of the special and unique quality of the brain of a person, any intervention threatening its integrity may be considered as an assault on personhood and autonomy.[32]

Other risks may also exist for society as a whole. For instance, such technologies may serve to increase competitiveness between persons or undermine equality if they become the reserve of the rich. Discrimination may then ensue, especially towards those who cannot afford, or refuse to use, the new interfaces.[33]

At the same time, due to the seriousness of the possible concerns, it is difficult to know what kind of policy developments and regulations will become necessary. Neuronal interfaces are likely to require constant vigilance as the quality and potential for connectivity increases. Indeed, there may be a need for redefining issues such as privacy, identity and what constitutes cybercrime. Legislation relevant to issues such as data protection and confidentiality may also have to be revised.

In this regard, the following policy dimensions would be important:

– The manner in which support is given to research and development of neuronal interfaces; because a significant amount of this research for both civilian and military purposes is supported by public money, society as a whole should be involved in deciding how these funds are used.

- The manner in which new neuronal interfaces are used for individual applications; because the way in which such applications may be used may challenge social values relating to the self, privacy, discovery, justice, health and rights, care is required when they are being considered in political settings.
- The manner in which the combined consequences resulting from neuronal interfaces may affect a population. This should, for example, examine the way in which neuronal imaging may be used to categorise personalities and how this could affect legal responsibility or equality of opportunity, such as in employment.[34]

A whole new structure addressing cybercrimes may also become necessary, though this will most likely be based on already-existing principles. As the report from the European Group on Ethics in Science and New Technologies to the European Commission concerning the ethical aspects of information and communication technologies implants in the human body indicated in 2005:

> [T]he legal background should be derived from general principles underlying national legislation and international instruments. Such general principles can provide the guidance required to outline the legal standards necessary for the regulation of a technology that modifies the body and its relationship with the environment and thereby impacts deeply on personal identity and life.[35]

These legal principles should be sourced from texts relating to the different relevant subject matters, such as international legal instruments on bioethics, data processing, privacy, the limitations on consent and the definition of medical devices.[36]

Of course, it is also important that the role of ethics in the context of policy and regulation should not only be reactive and restrictive, by addressing any misuses and harmful consequences, but also proactive, while looking to future possibilities. Ethical examination would then assist in the implementation of neuronal interfaces in society so that they can support beneficial outcomes, while improving the lives and welfare of citizens.[37] As Blank concludes: 'Brain policy, then can be permissive, affirmative, regulatory, or prohibitive.'[38]

However, new regulations may still be very different depending on whether neuronal interfaces are used in either medical or nonmedical contexts. Indeed, the manner in which the risks and advantages will be considered for appliances which do, or do not, have any medical purposes will be different.[39]

For an example of policy recommendations relating to neuronal interfaces, it is possible to consider those suggested by the Scottish Council on Human Bioethics, which can be found in the Appendix.

Notes

1. European Parliament, *Human Enhancement Study*, 90.
2. Ibid., 91.
3. Ibid., 92.
4. Ienca and Andorno, 'Towards New Human Rights', 8.
5. Ibid. 5.
6. Halder and Jaishankar, *Cyber Crime*.
7. Moore, *Cyber Crime*.
8. Harvey, *Can Histories of Previous Technological Breakthroughs?*; Wall, *The Future Challenges of Identity Crime in the UK*.
9. Bublitz, 'My Mind is Mine!?', 234, quoted in Ienca and Andorno, 'Towards New Human Rights', 10.
10. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 169–70.
11. Ienca and Haselager, 'Hacking the Brain'. The attack of a person's brain activity through unauthorised use of neurodevices by third parties is called 'brainjacking' in Pycroft et al., 'Brainjacking'.
12. Ienca and Andorno, 'Towards New Human Rights', 17–18.
13. DeVoe, 'Transhumanism and Crypto: Interview with Zoltan Istvan'.
14. Ienca and Andorno, 'Towards New Human Rights', 18.
15. Persson and Savulescu, 'The Perils of Cognitive Enhancement', mentioned in Ienca and Andorno, 'Towards New Human Rights'.
16. Wall, *The Future Challenges of Identity Crime in the UK*; Government Office for Science, Foresight, *Future Identities*, 30–31.
17. Ibid.
18. Wall, *Identity-Related Crime in the UK*.
19. Banerji, 'David Hemler'.
20. Government Office for Science, Foresight, *Future Identities*, 30–31.
21. Royal Society, *Brain Waves Module 4*, 5–6.
22. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 166.
23. Kanai et al., 'Political Orientations'.
24. Royal Society, *Brain Waves Module 4*, 5–6.
25. For example, see the use of natural experiments such as twin studies discussed in Rutter, 'Proceeding from Observed Correlation to Causal Inference'.
26. Morris, 'Second Life Affair Leads to Real-Life Divorce'.
27. Heim, *The Metaphysics of Virtual Reality*, 124; Waters, *From Human to Posthuman*, 56.
28. Parliamentary Assembly of the Council of Europe, *Technological Convergence*, para 9.
29. Peres, 'Israel Brain Technologies', quoted in Braude, 'Enhancing Cognition in the "Brain Nation"', 133.
30. Hook, 'Cybernetics and Nanotechnology', 64.
31. Blank, *Intervention in the Brain*, 68.
32. Ibid., 27.

33. Blank, 'Regulating Cognitive Enhancement Technologies', 247–48.
34. Blank, *Intervention in the Brain*, 79–80.
35. Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 13.
36. Ibid.
37. Chan and Harris, 'Neuroethics', 84–85.
38. Blank, *Intervention in the Brain*, 79–80.
39. Medicine and Healthcare Products Regulatory Agency, The Revision of European Legislation on Medical Devices, 10, quoted in Maslen, 'Toward an Ethical Framework', 286.

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Conclusion

Ever since the development of rudimentary tools and instruments in ancient history, humanity has used technology to overcome biological limitations. In this context, the original seventeenth-century Enlightenment idea that human beings can build a better future for themselves remains a very powerful and influential position. But it has also given rise to fundamental debates on the purpose of humanity, freedom of scientific enquiry, democratic government and individual liberty.[1] It is from this perspective of serious questioning that discussions concerning the possible biological enhancement of human beings have been taking place – a questioning that may be necessary for individuals to develop in modern society. As Norbert Wiener explains: 'We have modified our environment so radically that we must now modify ourselves in order to exist in this new environment. We can no longer live in the old one.'[2] This means that the hybridisation between human beings and machines may simply be the next step along the road of technoscientific history.

At the same time, however, it may be appropriate to be careful relating to the expectations of what will be possible in the near future. As the German ethicists Gerd Grübler and Elisabeth Hildt indicate: 'While an unrealistic understanding of . . . [neuronal interfaces] raises many of the most spectacular questions in ethics and metaphysics, the real existing . . . [neuronal interfaces] render them inadequate and require rather sober and detailed work in applied ethics and philosophical anthropology.'[3]

Yet, at the same time, direct neuronal interface systems already exist and will continue to be developed at a rapid rate by both academic and industrial stakeholders with important applications to:

– the sciences;
– defence and intelligence gathering;
– medicine; and
– the game and toy industry.

As such, it is certain that they will have a profound and significant impact on society. The Spanish biological scientist Rafael Yuste and others explain:

> It might take years or even decades until [neuronal interfaces] . . . and other neurotechnologies are part of our daily lives. But technological developments mean that we are on a path to a world in which it will be possible to decode people's mental processes and directly manipulate the brain mechanisms underlying their intentions, emotions and decisions; where individuals could communicate with others simply by thinking; and where powerful computational systems linked directly to people's brains aid their interactions with the world such that their mental and physical abilities are greatly enhanced.[4]

Within this context, however, the ethical challenges of future societies will need to be carefully examined. Yuste explains:

> Such advances could revolutionize the treatment of many conditions, from brain injury and paralysis to epilepsy and schizophrenia, and transform human experience for the better. But the technology could also exacerbate social inequalities and offer corporations, hackers, governments or anyone else new ways to exploit and manipulate people. And it could profoundly alter some core human characteristics: private mental life, individual agency and an understanding of individuals as entities bound by their bodies.[5]

What will actually be possible is only beginning to be considered and more discussions should be encouraged with respect to any long-term policy considerations. Moreover, at present, no specific legislations exist, either nationally or internationally, to regulate and control the use of such neuronal interfaces. This is because the technology is new and the current benefits of such systems generally exceed the potential risks, but this may change in the future.[6]

In 1931, Aldous Huxley published a book entitled *Brave New World*, which depicted a society in which human genetic engineering is ubiquitous and where happiness is controlled by biotechnology. A few years later, in 1949, another book was published, this time by the English novelist George

Orwell (1903–1950), entitled *Nineteen Eighty-Four*, which described a society that completely controls all its members in their everyday lives. When this latter book was published, Huxley sent a letter to Orwell indicating that he believed that the *Nineteen Eighty–Four* dystopia 'is destined to modulate into the nightmare of a world having more resemblance to that which I imagined in *Brave New World*. The change will be brought about as a result of a felt need for increased efficiency'.[7]

However, in 2015, Roger Strand and Matthias Kaiser from the University of Bergen in Norway came to a different conclusion indicating that:

> Whereas Orwell's 1984 mainly thematise[s] violent oppression, Brave New World creates the scenario of a world in which violent oppression no longer is needed because human desires for rights and freedoms have changed. Identity, dignity and integrity as we know it, have ceased to exist. We believe that the type of scenario presented by Brave New World is neither unthinkable nor necessarily unlikely anymore.[8]

This may mean that society should begin to earnestly examine, reflect and discuss the ethical dilemmas and possible social consequences arising, in the near future, from developments in neurotechnologies. Indeed, what was unthinkable by society at some stage in history often becomes reality more quickly than envisaged. As Braude explains:

> The temptation to improve society through improving mental capacity, or even shore up political power through neural interventions, is an issue that might seem futuristic but that requires close ethical foresight. The traditional bioethics principles of autonomy, beneficence, and justice are not penetrating enough to deal with these issues that may transform the neurobiological foundations of human liberty, instead they require sustained reflection in terms of biopolitics.[9]

With new developments in direct neuronal interface systems, it may indeed be possible in the future to control behaviour and thoughts by manipulating the brain under the initial pretext of enhancing the cognitive faculties of human beings. It may also be feasible for the mind of an individual to develop in cyberspace, raising questions about the identity, dignity and integrity of this person. As a result, there is certainly a need to consider any risks to freedoms that may arise from such new technologies. This is all the more complex because, as O'Brolchain and Gordijn explain, it may be possible for neuronal interfaces to be used for dual use, meaning that: 'Whilst they will offer many therapeutic and social benefits, they will also provide those with malevolent aims with greater control and knowledge, and thus with greater capabilities to cause harm.'[10]

In a pertinent essay entitled 'Dreaming with Diderot', written in 2007, the American sociologist and bioethicist James Hughes looks back at the book *D'Alembert's Dream*, written in 1769 by the French philosopher Denis Diderot, in order to discuss future possibilities. Accordingly, Hughes highlights the fictional philosophical dialogues between Diderot, his friend d'Alembert, a physician called Bordeu and an educated woman called Mademoiselle de L'Espinasse. In the discussion, Diderot suggests that since human consciousness is a result of the brain, the human mind can, in theory, be deconstructed and rebuilt to give the original.[11]

But whether Diderot's proposal may eventually be realised with the development and convergence of disciplines such as neurobiology, computer science, artificial intelligence and neuronal interfaces is an open question. However, what is certain is that human brains will increasingly be integrated with advanced computers because of the advantages these may offer. Human beings may then experience greater levels of sensations, such as sights and sounds, or be able to improve their memories and intelligence, while also avoiding fatigue and inattention. They may even be able to better control their emotions while being more resistant to depression, compulsion and mental disorders.

In addition, as artificial intelligence merges into human minds, it may be possible for humanity to deconstruct, rebuilt and redesigned itself in a manner that cannot yet be predicted.[12] D'Alembert asks: '[I]f everything is in a state of flux, as the spectacle of the universe shows everywhere, what might not be the result here and elsewhere of several million years of changes?'[13] In Diderot's book, the educated lady also points out that since the mind is connected by nerves to the body, all minds in the universe could be interconnected to one another (like a Universe Wide Web), to which the doctor responds that if such a web were to develop, it would be comparable to God.[14]

In a way, Diderot's discussion of such a possibility seems to herald many other later suggestions that humanity should aim to develop interconnectivity with machines and between individuals to form a community or collective.

However, it is impossible to predict whether such a community of all that exists would represent a utopian paradise or a dystopian nightmare in which the very individuality of a person is lost, absorbed or controlled by the collective.[15] The educated woman questions: 'Who knows what new species may once again evolve from such a huge mass of sensitive and living particles?'[16]

Human Autonomy

While there is much to welcome in the development of neuronal interfaces, especially when new biomedical applications are being developed, it is true that human bodies (including the brains) are beginning to be seen as things to master, take control over, redesign and enhance according to humanity's own desires. It is also worth noting that any influence of technology on the human brain goes to the very core of who a person is in society. As Blank explains: 'Neuroscience findings require a reevaluation of democratic concepts of equality, individual autonomy, freedom, and responsibility.'[17]

Yet, with respect to the way in which autonomy may be changed, the British social commentators Ed Brooks and Pete Nicholas explain that the virtual world may become attractive to individuals because they may be able to shape their own identity and be the person they want to be:

> In this world you are free from the constraints of your past and commitments of the present. You must decide for yourself who you are and what path you will follow. Let nothing get in the way. You are free to direct your own journey through life. You can avoid all those places that you would rather not travel to: places called failure and frustration and loneliness and loss and grief and guilt and disappointment.[18]

But risks also exist. For instance, if a government decided to influence and even control the way in which some members of the general public make decisions, this could be seen as a form of personal abuse. Moreover, if it is possible to read the intentions of a person to commit a crime, why should it not then be possible to act pre-emptively through a procedure where future criminals are arrested based on foreknowledge?

Yet, at the same time, there will always be limits to neurotechnology. As Cheshire points out: 'Although neuroscience has shed considerable light on the functions of the brain, it lacks the ability to explain the phenomena of consciousness, personal agency, conscience, moral responsibility, the continuity of identity over time, or human purpose.'[19]

It follows that if certain human aspects, such as free will and autonomy, involve more than the ability to just perform certain functions, then neuronal interface implants, whether they be therapeutic or enhancing, would not necessarily influence these aspects. This means that if a person's cognitive faculties, such as intelligence or memory, are enhanced through neuronal interface implants, this may give him or her more abilities, but not necessarily more free will. A depressed patient may be made to feel better through brain stimulation using a neuronal interface and this may represent a mood enhancement, but it does not modify his or her capacity to make independent decisions.[20]

Thus, full control of the human brain is unlikely to be achieved. It is only if an individual is completely taken over by a machine or another person in cyberspace that he or she would eventually become an automaton. But at the same time, caution is required since neuronal interfaces may still be able to affect an individual's sense of making his or her decisions. Consequently, developments in understanding the human mind and how it can be controlled should constantly be monitored.[21]

Similarly, with new applications of direct neuronal interfaces, it is important to consider the concepts of responsibility and sense of realism in terms of what can be achieved. Of course, this is already true in the realm of clinical applications, but should also be present in the military and gaming industries, since the risks may be considerable yet remain largely unknown.[22] This is one of the reasons why a continued engagement in cyberneuroethics is crucial.

Resistance to Such a Development

The possibility that some resistance in society may develop in relation to a continued evolution towards full-blown enhancement technologies and going beyond what is presently seen as normal in humanity should also not be underestimated. Thus, criticism may arise, expressing apprehension that becoming more than human undermines the very concept of humanity, with unforeseen consequences.[23] Similarly, concern may exist that humanity could eventually be affected by a sense of pride, or hubris, by what it can do, without examining all the possible risks and consequences.

On the other hand, a more positive approach may be considered if Enlightenment ideas are accepted, suggesting that the human mind is a direct consequence of the brain and that any concept of humanity should be seen as existing in a constant state of flux. If human beings then decide to go beyond the present notion of humanity, this could be seen as something that should be welcomed as progress and a natural development.[24] As Diderot indicated, one of the central themes of this debate is whether the human mind is unique to humanity and whether the concept of 'being human' has any moral relevance.[25]

Risks of Neuronal Interfaces

Of course, examining the proportionality between the risks and advantages of neuronal interfaces, and their applications in creating connections between the human mind and cyberspace, may seem slightly premature. Indeed, it is only recently that such interfaces have been applied to human beings and it is still difficult to appraise all the possible risks and side-effects of the new technologies against their perceived advantages. This means that many legitimate questions remain.

It is also impossible to predict how individuals would behave. For example, if it was possible to decrease suffering or increase life extensions, it is difficult to determine what kind of risks persons may be prepared to take. Diderot suggests that: ‘Vouchsafe a man, I don’t say immortality, but only twice his normal span, and see what will happen!’[26]

But real and practical applications already exist, which need to be considered. For instance, even if at present some interface systems are nonintrusive and reversible, their effects on the brain may themselves be irreversible, making it important to inform any potential users of their consequences. Moreover, the fact that some brain implants are less intrusive than other forms of treatment, such as neurosurgery, is not sufficient from an ethical perspective for them to be used without further questioning.

Neuronal interfaces and their applications in creating a connection between the human mind and cyberspace should also not be used in a manner that may undermine the very meaning of being a person, such as when the free will of an individual is taken away. This means that non-consensual treatment or compulsion can only rarely, and only in the most extreme circumstances, be justified for an individual patient or a wider class of patients or persons. Limiting autonomy can only be considered as a result of clear and objective medical criteria while respecting human dignity and the appropriate procedural safeguards.[27]

Another concern relates to the way in which this new technology is accessed, since it should not just be restricted to a rich minority who can afford it. Instead, it should be offered to as many individuals as possible so that societal inequalities can be redressed. For instance, if it is proved to be safe, wider access to cognitive enhancements procedures should be available to all who have cognitive limitations, even if they only have limited financial resources.

In the same way, any potential changes to a human being should always be considered in the light of protecting humanity as such. The educated lady in Diderot’s dialogue considered the possibility of deconstructing a mind of a genius for storage, and then reconstructing it to examine ‘memory, ability to make comparisons, judgement, reason, desires, aversions, passions, natural aptitudes, talent, and lo! My man of genius again’.[28]

However, creating geniuses who live forever without experiencing suffering cannot be the final aim of humanity if it is to remain human. Indeed, if suffering was completely eliminated through science and technology, important human capacities such as empathy, responsibility and even certain forms of sacrificial love would also be lost.

The French philosopher Simone Weil (1909–43) discussed the difficulty in recognising that science is the master of everything in the universe while still believing that there is a certain value and worth in humanity. As such, she warns that there is a very real danger of dehumanising individuals if science and technology are left to reign supreme as a force that cannot be constrained. In this she quotes the German politician and despot Adolf Hitler (1889–1945) in *Mein Kampf*,[29] who died after her, when he argued that humanity must never be so naive as to believe that it can be lord and master of the laws of Nature. Instead, he indicated that human beings must understand and accept the fundamental necessity of Nature's rule where physical scientific force alone is forever master. In other words, Hitler believed that there could be no special laws for humanity outside the laws of Nature.[30]

In this regard, Weil explains that such a belief expresses the only reasonable conclusion if a world is closed into, and reduced to, physical science. And, in a way, the whole of Hitler's life was nothing more than the implementation of this conclusion and what he believed to be true. Weil then suggests that those with a similar belief in the mastery and domination of the laws of Nature, science and technology may simply be fooling themselves in thinking that they are on a different road from him.[31] This implies that a different ethical view is necessary for humanity to flourish – one that does not imprison or reduce itself to science.

Society therefore needs to be careful in terms of always seeking to protect human dignity. That not everything will be positive in the future with the widespread use of neuronal interface systems should be acknowledged. Indeed, in Diderot's dialogues, his friend d'Alembert recognises that with some of these new technologies, human beings could eventually become some 'great, inert, motionless sediment'.[32] Similarly, James Hughes warns against the risks of a dystopian future, stressing that:

> We need guidelines and policies to steer human evolution away from dead ends of radical selfishness and addictive absorption, and towards greater sociability, self-awareness and reason. Even self-chosen brain engineering could make us all less than human, and we need instead to encourage one another to enhance the virtues that we value.[33]

Haraway also comments on the risk of 'fusion' of the different leading to 'confusion' by an undermining of clear differences.[34] At the same time and in discussing the 'cybernetic' term borrowed by Wiener, the British theologian and technology commentators, Scott Midson, asks: '[A]re humans still the steersmen of these [cyborgian] technologies; are humans still in control?'[35]

Careful and prudent discussions in cyberneuroethics are, therefore, necessary for humanity to protect itself from losing its humanity through the use of new direct neuronal interfaces. This means that society must remain vigilant in the face of future prospects, while trying to understand why it wants a different future from the present and, if it does, what kind of future it really wants.

Notes

1. Hughes, 'Dreaming with Diderot'.
2. Wiener, *The Human Use of Human Beings*, 56.
3. Grübler and Hildt, 'Introduction', 1.
4. Yuste et al., 'Four Ethical Priorities for Neurotechnologies and AI', 160.
5. Ibid.
6. Tracey, 'Neural Interfaces and Brain Interference', 31–37.
7. Letter from Aldous Huxley sent a letter to George Orwell, 21 October 1949, found at *Letters of Note*. Retrieved 21 October 2018 from http://www.lettersofnote.com/2012/03/1984-v-brave-new-world.html.
8. Strand and Kaiser, 'Report on Ethical Issues', 36.
9. Braude, 'Enhancing Cognition in the "Brain Nation"', 141.
10. O'Brolchain and Gordijn, 'Brain–Computer Interfaces and User Responsibility', 174.
11. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 158.
12. Hughes, 'Dreaming with Diderot'.
13. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 179.
14. Ibid., 184–85.
15. Hughes, 'Dreaming with Diderot'.
16. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 176.
17. Blank, *Intervention in the Brain*, 78.
18. Brooks and Nicholas, *Virtual Humanity*, 81.
19. Cheshire, Jr., 'The Sum of All Thought', 139.
20. Barker, 'Health Care/Medical Treatment', 68–69.
21. Strand and Kaiser, 'Report on Ethical Issues', 4.
22. Nuffield Council on Bioethics, *Novel Neurotechnologies*, 173.
23. Hughes, 'Dreaming with Diderot'.
24. Ibid.
25. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 180–82.
26. Ibid., 164.
27. Barker, 'Health Care/Medical Treatment', 66–67.
28. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 219.
29. Hitler, *Mein Kampf*, vol. 1, Chapter 10.
30. Ibid.
31. Weil, *L'enraciment*, 156–59.
32. Diderot, *Rameau's Nephew/D'Alembert's Dream*, 176.
33. Hughes, 'Dreaming with Diderot'.
34. Haraway, 'Staying with the Trouble', 104.
35. Midson, 'Cyborg Theology', 101.

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Appendix

Scottish Council on Human Bioethics Recommendations on Cyberneuroethics

The following recommendations were agreed by the Scottish Council on Human Bioethics and represent the first example of guidelines from a European ethics council on the topic of cyberneuroethics.

Because different council members had different views concerning the strengths and weaknesses of the arguments in this book, it is not possible to describe the manner in which the recommendations were decided. The recommendations do, however, represent the general consensus of council members.

Recommendations on Cyberneuroethics

Changing Cognition

– The freedom of persons with a limiting mental disability to increase their cognitive functions should be protected.

Free Will and Moral Responsibility

– Everyone should have the right to freedom of thought, conscience and religion; this right includes freedom to change his or her religion or belief.[1]

– Freedom to manifest one's religion or beliefs should be subject only to such limitations as are prescribed by law and are necessary in a democratic

society in the interests of public safety, for the protection of public order, health or morals, or for the protection of the rights and freedoms of others.[2]
– Neuronal interfaces should not be able to affect a person's free will and responsibilities.

Changing Consciousness

– Neuronal interfaces used with the aim of controlling, coercing or dominating others should be prohibited.[3]

Escaping Reality

– Neuronal interfaces should not be used to enable a permanent escape from reality.
– Non-enhanced persons should not be subject to any discrimination of any kind.[4]

Changing Mood and Personality

– The freedom of persons to use neuronal interfaces to improve their moods or personality in a positive fashion should be protected.

Changing Dysfunctional Thoughts and Emotions

– The freedom of persons to use neuronal interfaces to address severe mental disorders in which thought and emotions are so impaired that contact is lost with external reality (psychosis) should be protected.

Changing Identity

– Neuronal interfaces should not be used without a person's consent if the primary aim is to change his or her identity, mental function, self-perception and perception of others.[5]

The Concept of Humanity

– The freedom of persons to enhance their human bodies (including their brains) through technology should be protected.
– Persons should never become something other than human.
– The dignity and identity of all human beings should be protected.[6]
– The physical and mental integrity of all human beings should be protected.[7]

– A partial combination of the human mind with cyberspace should always guarantee the integrity of the human being.
– The interests and welfare of the human being shall prevail over the sole interest of society or science.[8]

Uploading a Mind

– Human beings should not seek to create new persons by uploading their minds into cyberspace.
– A complete communion of minds in cyberspace should not be permitted.

Issues of Privacy

– Everyone should have the right to respect for his or her private and family life, his or her home and his or her correspondence.[9]
– There should be no interference by a public authority with the exercise of the right to privacy except such as is in accordance with the law and is necessary in a democratic society in the interests of national security, public safety or the economic wellbeing of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others.[10]
– Reading the minds of other persons should only take place with their appropriate informed consent.
– The skull and all that it contains should be a controlled and protected privacy zone.
– The privacy and confidentiality of data obtained from neuronal interfaces should be guaranteed.[11]
– Individuals should have a right to determine what data about themselves should be processed, by whom and for what purpose.[12]

New Cybercrimes

– A real person should be held responsible if he or she commits a crime in cyberspace that may have real consequences on other real persons or organisations.

Policy Concerns

– A broad social and political debate should be initiated to examine what kind of neuronal interfaces should be accepted and legally approved, particularly concerning surveillance and enhancement.[13]

– National and international ethics councils (or similar institutions) should create conditions for education and constructive, well-informed, debates in the areas of neuronal interfaces and the resulting interactions between the mind and cyberspace.[14]
– The precautionary principle should be invoked when serious risks exist relating to neuronal interfaces. In particular, it should be possible to distinguish between:[15]
  – Active and passive interfaces,
  – Reversible and irreversible interfaces,
  – Offline and online interfaces, and
  – Medical and non-medical applications.[16]
– Because of the principle of integrity and inviolability of the human body, a person's consent should not be sufficient for an interface to be used.[17]
– A person's consent to use neuronal interfaces should be able to be withdrawn at any time.

Notes

1. This reflects Article 9 of the Council of Europe Convention for the Protection of Human Rights and Fundamental Freedoms.
2. This reflects Article 9 of the Council of Europe Convention for the Protection of Human Rights and Fundamental Freedoms.
3. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 32–35.
4. This statement does not presuppose that the specific behaviour of a person should always be accepted.
5. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 32–35.
6. Based on Article 1 of the Council of Europe Convention on Human Right and Biomedicine.
7. Based on Article 3 of the EU Charter of Fundamental Rights.
8. Based on Article 2 of the Council of Europe Convention on Human Right and Biomedicine.
9. This corresponds to Article 8 of the Council of Europe Convention for the Protection of Human Rights and Fundamental Freedoms.
10. This corresponds to Article 8 of the Council of Europe Convention for the Protection of Human Rights and Fundamental Freedoms.
11. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 32–33.
12. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 32–33.
13. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 33–35.
14. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 33–35.

15. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 20–21.
16. This corresponds to the regulations in Opinion No. 20 of the Secretariat of the EGE, *The Ethical Aspects of ICT Implants in the Human Body*, 20–21.
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Glossary

Big data: a broad term for datasets and information that are so large or complex that they cannot be processed by standard applications.

Bionic: refers to the replacement or enhancement of organs or other body parts by mechanical applications. Bionic implants differ from prostheses by mimicking the original function very closely, or even surpassing it. The term may have been coined from the ancient Greek 'bion', meaning 'unit of life' and the suffix 'ic', meaning 'like' or 'in the manner of'. Alternatively, it may have come from the terms 'biology' and 'electronics'.

Brain–computer interfaces: a direct interface between a brain and a computer system.

Closed-loop system: a system that has the following major components: (1) the participant; (2) signal acquisition; (3) signal analysis; and (4) signal feedback.

Cloud computing: the storage and processing of data in third-party data centres.

Cognitivism: asserts that computational states are necessary for minds.

Computed tomography (CT): a procedure that uses X-rays to visualise brain anatomy in sections.

Consciousness: the quality or state of being aware of an external object or something within oneself.

Cyborg: implies an undefined relationship between the cybernetic and the organic. The Cyborg deliberately incorporates nonliving components into a living organism so that it can be adapted to new environments.

Cyberpunk: a subgenre of science fiction featuring advanced technological and scientific achievements, such as information technology, giving rise to a degree of breakdown or radical change in social order.

Data mining: extracting information from large quantities of data and transforming it into an understandable structure for further use.

Electroencephalogram (EEG)/magnetoencephalography (MEG): using electrodes (EEG) or sensors (MEG) attached to the scalp to measure activity. These detect very small electrical currents and associated magnetic fields from the aggregate activity of many hundreds of thousands of neurons. The procedures can directly measure neuronal activity and has superior temporal resolution in comparison to the indirect measurements of fMRI.

Enhancement: the use of technology and science to increase the human functioning of a healthy individual beyond the norm for that person and in the absence of any identified dysfunction. However, it does not generally include the creation of capacities in beings that have never previously existed in humans (which may be considered under the concept of transhumanism).

Functional MRI (fMRI): an imaging procedure that measures changes in the oxygenation level of the blood and that can detect aspects of neuronal activity if used on the brain.

Haptic (or kinesthetic) communication: technology used to re-create the sense of touch to the user by applying forces, vibrations or other motions.

Implantable medical device: a medical device that is intended to be totally or partially introduced into the human body or by medical intervention into a natural orifice and that is intended to remain after the procedure.

The Internet of things: represents the network of physical objects embedded within electronics, software, sensors and connectivity, enabling them to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices.

Locked-in patients: patients who retain cognitive functions or who have a minimally conscious state, but who cannot move or communicate verbally due to complete paralysis of nearly all voluntary muscles in the body.

Metaverse: the space created when physical reality is enhanced by a virtual space. The word is derived from the prefix 'meta' (meaning 'beyond') and 'universe'. It is normally used to describe a future version of the Internet in which persistent, shared, three-dimensional virtual spaces are linked to create a perceived virtual universe.

Monads: self-contained and secluded nonmaterial entities with no spatial or physical properties expressing rational or autonomous activities (from the Greek *monas* meaning 'singularity' which is itself derived from *monos* meaning 'alone').

Nerve: composed of different types of axons through which electrical nerve impulses are transmitted.

Neural: characterises what is associated with nerves or the nervous system.

Neuroessentialism: the belief that moral identity can be reduced to the brain.

Neuronal: characterises what is associated with neurons.

Neuronal interface systems: describe a range of devices that enable a network of neurons to be connected with an appliance. This can include interfaces between neuronal networks and machines such as between a brain and a computer. These neuronal interfaces can usually be classified in one or more of the following categories:

> **Direct neuronal interface systems:** a range of devices that enable a network of neurons to be directly connected with an appliance.
>
> **Input neuronal interface systems:** provide stimulation to specific parts of the nervous system.
>
> **Output neuronal interface systems:** record signals from neuronal networks. These can be used in two possible ways:
>
> > **Open-loop prediction neuronal interfaces:** record neuronal activity from multiple sites to predict behaviour.

Closed-loop control neuronal interfaces: record neuronal activity to guide a device. The user then receives sensory feedback and is able to learn to better control the system in the future.

Passive neuronal interface systems: record the user's neuronal activity and converts this information into instructions. Used in a game, for example, this could adjust general parameters to sustain a desired state of immersion.

Active neuronal interface systems: record the user's neuronal activity, but enables him or her to deliberately alter his or her level of brain activity to control the equipment. In a game, the user might imagine movement to make a character move on a screen.

Reactive neuronal interface systems: record neuronal activity that is triggered by the user responding to events. This may be an uncontrolled reaction to sudden loud noise or the appearance of a particular character or feature in a game.

Neurons: the cells present in the brain, spinal cord and peripheral nerves.

Neuroprosthetics: artificial devices that restore or replace a missing brain function that has been lost through trauma, disease or congenital conditions.

Positron emission tomography (PET): a procedure in which a radioactive tracer molecule is injected into the body whereby detectors placed around the head or other body part being imaged can sense the radioactive decay of the tracer molecule. This allows the reconstruction of images of the brain or other organs where the image is sensitive to the particular molecule used.

PET allows for both measurement of blood flow changes consequent to brain activity as well as the distribution and quantity of specific brain receptors, so long as a radio-ligand that targets that receptor can be synthesised.

Posthumanism: the idea that possible future beings that originated from humans or humanity can be developed, whose basic capacities so radically exceed those of present humans as to no longer be considered as human in any significant degree or form.[1]

Prosthesis: an artificial device that replaces a missing body part that has been lost through trauma, disease or congenital conditions. From the ancient Greek *prósthesis* ('addition, application, attachment'), such a device is also used to help a person 'look' more normal.

Right to be forgotten: the perceived right for individuals to determine the development of their life in an autonomous way, without experiencing discrimination as a consequence of a specific past action.

Strong artificial intelligence: asserts that computational states are necessary and sufficient for minds to exist.

Structural Magnetic Resonance Imaging (MRI): an imaging procedure that measures brain anatomy using a strong magnetic field combined with radio frequency waves.

Transhumanism: the idea that humanity can transcend or overcome the limitations of human nature.[2] Transhumanism is different from the concept of enhancement in that it seeks to create beings that have never previously existed in the history of humankind. These beings would retain some human characteristics, such as with human-nonhuman interspecies beings or cyborgs that combine the human and the robot. Transhumans should, however, be distinguished from posthumans.

Virtual reality: replicates an environment that simulates physical presence in both the real or imagined worlds and lets the user interact in that world. This usually takes place through a computer screen, though other infrastructures may also be used.

Voxel: represents each of an array of elements of volume that constitute a notional three-dimensional space, especially each of an array of discrete elements into which a representation of a three-dimensional object is divided.

WiFi: represents wireless fidelity technology for wireless local area networking with specific electronic devices.

World Wide Web: an information space where documents and other web resources may be identified, interlinked and accessed via the Internet.

Notes

1. Savulescu, 'The Human Prejudice and the Moral Status of Enhanced Being', 214.
2. McNamee and Edwards, 'Transhumanism, Medical Technology and Slippery Slopes', 513–18.

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