Brain Computer Interfaces and Human Rights: Brave new rights for a brave new world

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ABSTRACT

Digital health applications include a wide range of wearable, implantable, injectable and ingestible digital medical devices. Many of these devices use machine learning algorithms to assist medical prognosis and decision-making. One of the most compelling digital medical device developments is brain-computer interfaces (BCIs) which entails the connecting of a person's brain to a computer, or to another device outside the human body. BCIs allow bidirectional communication and control between the human brain and the outside world by exporting brain data or altering brain activity. Although being marveled at for its clinical promises, this technological advancement also raises novel ethical, legal, social and technical implications (ELSTI). Debates in this regard centers around patient autonomy, equity, trustworthiness in healthcare, data protection and security, risks of dehumanization, the limitations of machine learning-based decision-making, and the influence that BCIs have on what it means to be human and human rights. Since the adoption of the Universal Declaration of Human Rights (UDHR) after World War II, the landscape that give rise to these human rights has evolved enormously. Human life and humans' role in society are being transformed and threatened by technologies that were never imagined at the time the UDHR was adopted. BCIs, in particular, harbor the greatest possibility of social and individual disruption through its capability to record, interpret, manipulate, or alter brain activity that may potentially alter what it means to be human and how we control humans in future. Cutting edge technological innovations that increasingly blur the lines between human and computer beg the rethinking and extension of existing human rights to remain relevant in a digitized world. In this paper sui generis human rights such as mental privacy, the right to identity or self, agency or free will and fair access to cognitive augmentation will be discussed and how a regulatory framework must be adapted to act as technology enablers, whilst ensuring fairness, accountability, and transparency in sociotechnical systems.

KEYWORDS

brain computer interfaces, human rights, neurological privacy, autonomy, identity

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1 THE NEW FRONTIERS OF BRAIN COMPUTER INTERFACES

Our thoughts, decisions, actions, emotions, imagination and memories derive directly from the complex network of neural circuits in our central nervous system, which is why it is important to consider the impact that neuro technologies, such as Brain Computer Interfaces (BCIs), may have on our ability to make autonomous decisions, mental privacy, human identity, and the security of the computer systems we may integrate with [1]. Although BCIs are groundbreaking in many aspects, some legal-ethical issues relating to certain human faculties have been grappled with for quite some time, such as the implantation of false memories of traumatic or transformative events through verbal and visual suggestion, which has been done for more than 30 years [2]. Subsequently, to prepare for and protect against novel threats posed by BCIs, we need to understand and anticipate the new frontiers of BCIs and related technologies.

Neuroscience is making important inroads into the diagnosis and treatment of many neurological conditions, including addiction, chronic pain, dementia, depression, epilepsy, multiple sclerosis, Parkinson's disease, schizophrenia, stroke, and traumatic brain injury [3]. But to ensure effective and safe progress in this regard, a better understanding, through research, of the complexities of the brain is necessary.

For these reasons the United States launched a large-scale, long-term scientific project called BRAIN – Brain Research through Advancing Innovative Neuro-technologies in 2013 [4]. In addition to its research activities, this initiative will also develop electronic, optical, molecular and computational tools that will "record brain activity or *interfere with it*, using both invasive devices (inside the brain) or non-invasive devices (attached to the skull)", with intervention tools being one of the initiative's priority areas [4]. Interventional tools, and more specifically BCIs, involves the connecting of a person's brain to a computer or other device outside the human body which connection will create a bidirectional communication and control channel that can export and manipulate brain activity, which will ultimately enable a new generation of tools for optogenetics, chemo-genetics, and biochemical and electromagnetic modulation [5].

For example, some of these technologies use a combination between deep-learning algorithms and natural-language models that yield next-word probabilities to create computational models that can detect and classify words from patterns in a person's recorded cortical activity which is a valuable technology to restore the ability to communicate in paralyzed persons who cannot speak, which should improve the person's autonomy and quality of life [6]. Other technologies explore the information captured in functional magnetic resonance imaging (fMRI) records of the brain via a method called 'brain decoding' which was developed to use the patterns exhibited by the coloured blobs on the fMRI scans, that lit up as a result of receiving oxygenated blood, to measure activity of the brain, which patterns were then associated with certain pictures or concepts with the help of computer algorithms that served as 'pattern classifiers' [7]. Once this program identified and classified enough patterns it will even be able to deduce what the person is looking at or thinking about, or produce a primitive-looking movie about what the person was viewing based on his or her brain activity [8]. These technologies show that the brain is essentially a computer that evolved and developed over time based on the input from our sensory and lived experiences. Although BCIs and similar devices can speed up this evolutionary process and revolutionize the medical, communication and other industries, they also harbor the potential to destroy our neurological privacy, identity of self and expose us to malicious hackers. Brain activity generates not only conscious thoughts, but also subconscious ones, and the recording of brain activity will sooner or later also allow access to our subconscious.

Many BCI researchers envision a future where people are seamlessly connected to each other and the world that surrounds them, where information and context can be retrieved through mere eye contact, or by typing directly from our brains [9]. Neuralink is one of several companies that are already actively working towards connecting human brains to the internet in an effort to amalgamate mind and machine [10], whilst companies such as Kernel is developing neuro prosthetics with the aim to increase human intelligence [11]. A team of biomedical engineers at the University of Witwatersrand (Wits) in Johannesburg, South Africa, in a project called Brainternet, actually managed to stream human brain waves to the internet on an open-source website which will enable the future transfer of information both as inputs and outputs to the brain [12]. The novelty of this technology lays in its connectivity, interactivity, and usage of brain waves to execute tasks, as opposed to merely translating brain activity across the internet. Along similar lines researchers in California developed a simulator which can transmit information directly to your brain and teach you new skills, such as flying a plane, in a short amount of time [13], whilst researchers at Duke University in Durham, North Carolina, showed that three monkeys, with electrode implants, could collectively move an avatar arm through the 'brain net' that these connected implants created [14].

These technologies took a further leap forward when researchers transferred information directly between two brains via an approach they called "brain-to-brain" interfacing (BTBI) [15], including with cross species neural interfacing in which information was transferred from human to rat brains by recording signals from a human scalp and transforming it into tail-movement-evoking stimulation delivered to the brain of an anesthetized rat, extending BTBI to another species [16]. Such developments suggest that in future it may be possible to reverse the direction of interspecies BTBI, from non-human animals to humans, which may enhance our sensory systems, for example, by linking our olfactory systems to that of a dog which may assist search-and-rescue operations.

BCI and related technologies will be able to connect our brains to the Internet of Things (IoT) around us and empower humans in ways that we have never dreamt of before. These transformative technologies will over the long term change the way we communicate, view intelligence and the value of studying, how we guard our knowledge, how we adapt to a new sense of self-identity, experience and act with empathy, and how we reorganize societies. This may put us on a knife edge between utopia and utter destruction. Not only can these technologies be used to monitor and measure your emotions, but it may also be used for coercive purposes. In North America BCIs are already commercially marketed to monitor attention deficit through so-called neuro gaming that allows access to your performance, as well as direct access to information stored in your brain, including your identity number, social security number, and banking particulars [17]. Your neuro-data thus serves as another method of identifying you, much in the same way as your genes and finger prints do.

To truly exploit the positive life changing impact that these technologies may have, much more data and analysis is needed to safely and securely implement these technologies – including legal protection to safeguard the novel areas of human beings that are now being disclosed such as out inner thoughts, emotions, and preferences – our neurological existence.

2 SAME HUMAN RIGHTS, CHANGING CONSTITUTIONS

Beitz propose a broad practical conception of human rights and describe them as "requirements whose object is to protect urgent individual interests against predictable dangers ('standard threats') to which they are vulnerable under typical circumstances of life in a modern world order composed of states" [18]. This definition contains important elements when considering whether to create new human rights in the context of neurological technologies and to prevent so-called 'rights inflation' which refers to the tendency to label everything that is morally desirable as a 'human right' [19].

The Geneva Protocol, a treaty banning the use of chemical and biological weapons was developed after the First World War in 1925 [20], and after the Second World War, the UN Atomic Energy Commission was established, which is now called the International Atomic Energy Agency, to promote the safe, secure and peaceful use of nuclear technologies [21]. World War II also gave rise to the first human rights as codified in the Universal Declaration of Human Rights (UDHR) [22]. However, since the early 1900s human life, and more specifically humans' role in society has been dramatically transformed by emerging technologies that were unimaginable at the time when the UDHR was written. In view of the above discussed emerging technologies and their possible consequences to humans and society, it is clear that these technologies will increasingly blur the boundaries between human and computer, which necessitates the rethinking of existing human rights, and their enforcement, to ensure that human rights in general remain relevant and applicable in a digitized world. Yuste et al. believe that these existing international regulatory instruments, including the 1979 Belmont Report [23] which was created to protect human subjects from biomedical and behavioural research, and the Asilomar artificial intelligence (AI) statement [24] of cautionary principles, are insufficient to protect humans against neuro-technologies [25]. The Asilomar principles, created in 2017, outline AI developmental issues, ethics and guidelines for the development of beneficial AI and how to make beneficial AI development easier, but does not contain any specific principles regarding the protection of unique human rights that came under the spotlight through the implementation of neuro-technologies. These principles merely reiterate already existing legal and ethical rights, including the responsibility to take moral implications into account when designing and building advanced AI systems (principle 9); aligning highly autonomous AI systems with human values (principle 10); designing AI systems to be "compatible with ideals of human dignity, rights, freedoms, and cultural diversity" (principle 11); personal privacy and the right to access, manage and control the data they generated or given to AI (principle 12); preventing the unreasonable curtailment of people's real or perceived liberty (principle 13); providing the freedom of choice in delegating decisions to AI systems to accomplish human-chosen objectives (principle 14); that advanced AI systems should "respect and improve, rather than subvert, the social and civic processes on which the health of society depends" (principle 17); and that risks posed by AI systems, especially catastrophic or existential risks, must be subject to planning and mitigation efforts commensurate with their expected impact (principle 21) [24].

Although neurosciences share many of the ethical issues raised across scientific fields, certain finer nuances relating to privacy, such as the privacy of our thoughts, threats to our autonomy and self-determination, or how we identify ourselves and fit into society are definitely unique considerations probed by emerging neuro-technologies [26].

The internet, with which BCIs will increasingly be connected in future, is run by a transnational private regime of big-tech companies which makes the governance of the internet, which is currently based on modern constitutionalism guided by the sovereign authority of nation-states, increasingly difficult [79]. This gives way to the situation where the internet ecosystem demands a greater level of fundamental rights protection, but lacks the necessary structural feasibility to effectively provide these rights. It is in this context that the concept of digital constitutionalism originated, and was defined by Gill et al. as "a constellation of initiatives that seek to articulate a set of political rights, governance norms, and limitations on the exercise of power on the Internet" [80]. On the internet, where private multinational companies are active and dominant role players, next to nation states, it is the state-centric nature of standard constitutionalism that demands a conceptual rethinking of constitutionalism in the context of this borderless and global digital ecosystem [81]. Various civil society groups and multinational technology corporations affirm their digital rights via a patchwork of legally binding and non-binding legal sources, including non-binding declarations, making use of democratic and institutionalised processes. Many of these documents have a political, as opposed to technical primary, and do not aim to protect an ideal-type architecture, but rather the fundamental rights of human beings against threats posed by "a historically determined assemblage of design, codes, infrastructures and usages" [79]. In this regard the international regulatory order of the internet has moved from a state-centric normative architecture towards an increasingly individual dimension [82]. This digital constitutionalism aims to return political concerns and perspectives, informed by economic and technical realities, back into the governance of the internet, and to ground the political struggle over the internet explicitly in the fundamental rights of individuals [80]. In this legal discourse, sovereigntists aspire to subject the internet to state-centered instruments such as national laws and governmental policies, whilst digital constitutionalists aspire to a normative framework informed by international human rights law, as well as domestic democratic constitutions. The argument in favour of digital constitutionalism is that international laws will focus on human rights, as opposed to interstate relations, which may result in a single integrated 'individual-oriented' system [83]. This will ensure that international law acquires a new constitutional function by supplementing domestic laws in these global, and in this case digital, challenges.

In this context and in the absence of any specific regulations the precautionary principle, a generally accepted principle that was created in the Declaration on Environment and Development, adopted in Rio de Janeiro in 1992, which scope and application is considered to extend beyond the EU or environmental matters, and has been codified in numerous international instruments, can be applied as a principle to facilitate decision-making under scientific uncertainty [27]. In this regard Principle 15 of the Rio Declaration states that the "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" [28] from which we can deduce that when an activity, such as those proposed by BCIs, raises threats to human health (either physically or mentally), "precautionary measures should be taken, even if some cause-and-effect relationships are not fully established scientifically" [29]. Thus, to limit, regulate of prevent potentially dangerous technologies – even before scientific proof has been established – four components need to be considered: 1) the potential threat; 2) the uncertainty; 3) the fact that an action is required that will limit, regulate, or prevent the harm; and 4) the fact that precautionary steps are mandatory [30]. The possibility of harm in combination with scientific uncertainty serve as trigger for the taking of preventative actions, that should preserve respect, not only for the human body, but also the human mind. Applied as such the precautionary principle is a dynamic tool, the application of which can equally evolve with the evolution of neuro-technologies to continuously verify the acceptability of the conditions in which these technologies are being implemented.

In addition to using precautionary principles, the success of responsible neuroscience depends largely on continual dialogues between neuro-scientists, ethicists, philosophers, lawyers, and other stakeholders to shape the creation of regulatory frameworks that will sufficiently protect humans, whilst still allowing innovative scientific developments to thrive [31]. Spearheading such a movement is the NeuroRights Initiative formed by Columbia University under leadership of neuroscientist Rafael Yuste, in collaboration with the Neuro Rights Foundation in New York, US, whose aim it is to convince governments across the world to create so-called "neuro rights" to legally protect extended human rights in line with the UDHR [32, 33]. Where the Asimolar AI Principles were focused on the responsible implementation of AI technologies, the BRAIN 2025 Report is focused on research and highlights four scientific goals in this context which entails the 1) establishment of a shared vision for the ethical conduct of human neuroscience research; 2) collection and dissemination of best practices in the conduct of ethical scientific research; 3) support of data-driven research to inform ethical issues arising from BRAIN Initiative research; and 4) the development of outreach activities to engage diverse stakeholders in discussions about social and ethical implications of neuroscience research [34]. Many, if not all of the ethical issues that arise in the context of research are already regulated by various international instruments such as the Declaration of Helsinki and the Belmont Report, and are often also embedded in national legislation. It is the ethical issues that arise when considering the long-term implementation and use of neuro-technologies that need discussion and regulation. The Neuro-ethics Guiding Principles proposed by Greely et al. is a first step to identify the ethical challenges that are unique to neuro-technologies, with the view of assisting scientists to navigate the difficult questions that will be prompted by research from the NIH BRAIN Initiative [31]. Although the Presidential Commission for the Study of Bioethcial Issues was mandated to, amongst other, proactively identify a set of core ethical standards, not only in respect of neuroscientific research, but also with regards to "ethical dilemmas that may be raised by the *application* of neuroscience research findings", volume 1 of their report primarily still focusses on ethics education and the integration of ethics throughout the research cycle, as opposed to the ethical issues that may arise when neurological technologies will be implemented [35]. In similar vein the European Brain Council (EBC), established in 2002 and constituted by all major scientific and clinical societies working in the field of brain science and brain disorders in Europe, guards the quality, scope and ethics related to neuroscientific *research* in Europe [36]. On the other hand, and although perhaps a bit cryptic, the 2019 OECD report on Responsible Innovation in Neurotechnology does contain a set of guiding principles for the protection of cognitive liberty and autonomy, guarding against social inequality and potential exacerbations of it through neurotechnology [37].

Neuro data is intimate and sensitive data, even more so than biodata, and subsequently needs better protection than what is currently available, as discussed above. Advancements in neurotechnologies are entering human spaces that have, up to now, remained hidden, private and secret, which, for the first time requires humans to protect themselves against direct manipulation, erosion of autonomy, unintentional sharing of data, and mental coercion. Suddenly our secrets make us vulnerable, but without them there will be no perspective, subjectivity, creativity, interiority, or our inner life, which ultimately make us human and our lives so valuable. Below I shall discuss a few of the major aspects of our human lives that will be impacted most by neuro-technologies.

2.1 Neurological privacy

Being connected to each other via various devices such as smartphones makes accessing and sharing of personal data easy, but also problematic from a data privacy point of view. Unauthorised access and sharing of data is further complicated and exacerbated by neurotechnology, because the data that these technologies generate and manipulate consists of the neural activity of the individual. While you can control and filter what and how you communicate or engage with the outside world, your neural activity or neurological data may involuntarily reveal information which you would have chosen to filter in some way or keep secret from the world outside your head. Your ability to control access to your brain data and to safeguard the privacy of your thoughts may become increasingly difficult as neuro-technologies advance and evolve. Neurological privacy seems to be the final frontier to be crossed where after we may be deprived of any form of privacy. Neurological data can be used, in combination with existing personal data, to enrich already robust personal data profiles by externalizing information that was previously hidden and kept private by deliberate personal choice.

While considerable efforts have been made to protect genetic information, similar protections for neural data does not exist. This is ironic because where one has little control over the genes that you inherit, although epigenetic changes may occur, neural data is the direct result of your own, fully controlled thoughts, molded and enriched by your sensory inputs and lived experiences, which makes neural data so much more sensitive than genetic data.

A related privacy concern involves the transmission of extracted neural information from the human brain to a computer network, or another brain, which transmission is seemingly introduced into the receiving device, network or brain without the receiver being able to refuse or inhibit the impulse [38]. This may allow for the introduction of various kinds of information coercively and the use of such technologies coercively. Theoretically, if thoughts or behavior can directly be inserted into the brain of a person through a BCI, without his or her consent or co-operation, this may lead to the behavioural manipulation, exploitation, or abuse of vulnerable groups in this context, such as prisoners or soldiers, for example.

New insights into brain activity brought about by neuroimaging technologies such as computed tomography (CT), positron emission tomography (PET), electroencephalography (EEG), and functional magnetic resonance imaging (fMRI) raise further unique questions about privacy, especially with regard to a person's ability to decide whether, when, and how neural data may be accessed or used [39]. When neuroimaging technologies are deployed in the judicial system for purposes of crime prevention, lie detection, or to make inferences about criminal intent, it raises additional privacy concerns, especially in light of an accused's right to silence [40]. Several studies already focus on the use of neuroscience for law enforcement purposes and are investigating the use of fMRI to investigate questions about deception [41, 42].

It is clear that the general and existing right to privacy must be extended and defined in greater detail to also include the right to neurological privacy to protect our thoughts and inner sanctum of being. This extension is also needed to protect people against themselves in circumstances where they may be enticed to trade their neural activity data for discounts, insurance, access to social media platforms, or to keep jobs. Factory workers in China are already forced to wear devices that monitor their mental states to improve worker efficiency [43]. Such brain transparency gives an entirely different meaning to the concept of data privacy, which will severely limit or even prevent people from criticizing political parties, employers, contemplating their sexual orientation or religious preferences. Although freedom of speech currently enjoys legal protection, it is questionable whether freedom of speech can also be interpreted to extend to the protection of freedom of thought, considering that thoughts do not necessarily and always result in actions.

This extended right to neural privacy should also provide for the safe and secure technical storage and protection of any data extracted via neural recording techniques [44].

2.2 Autonomy

The ethical principle of autonomy, based on the Kantian claim that one should always respect human beings by treating them as persons instead of mere resources, manifests in practice by respecting people's rights and choices [45]. However, the sense of having autonomy, especially in view of neurotechnological interventions, may sometimes differ from the real existence and exercising of autonomy where the individual is actively making the decisions [46]. This disconnect between real autonomy and a sense of autonomy becomes increasingly complex when the shift from human to device decision making is implicit in the control exercised by "intelligent" BCI devices. For example, a person may be under the impression that he or she is choosing or causing a BCI to execute a certain action, such as a BCI-controlled robotic arm picking up an object, when in fact it is the "intelligent" BCI that operates independently from the human decision, based on the visual inputs and artificial intelligence it collected from the human that accurately predicts what the person wants.

Dementia or Alzheimer's disease may pose further interesting ethical issues related to autonomy and the use of BCI prior to the onset of symptoms associated with these conditions. Neurological changes caused by Dementia or Alzheimer's disease may profoundly change a person's wishes and preferences, especially when the condition progresses. Decisions that such a person may have taken prior to onset of the disease, or upon worsening of the condition may no longer be appealing to the same person once the symptoms have progressively become worse. This raises questions about how "intelligent" BCI devices will "interpret" changes in the visual and artificial intelligence it collects from such a person and to what extent the actions executed will reflect the changes in such a person's changed perceptions and behavior. Some philosophers and ethicists have argued that to respect a person's autonomy in these circumstances entails the respecting of the person's earlier autonomous preferences [47], whilst others counter argued that priority must be given to the person's changed and current preferences, which might be significantly different from their earlier preferences [48]. In the absence of ethical consensus in this regard, the addition of BCI may only add another layer of complexity to the debate regarding ethical difficulties encountered when pre-dementia autonomy and post-dementia autonomy are in conflict [49].

BTBIs further necessitates us to rethink the whole concept of autonomy and its protection. BTBIs create a novel means of information transfer which bypasses the customary sensory means of a person's brain to consider information from another person, which essentially prevents a person, fitted with a BTBI, from freely choosing and exercising a decision based on his or her own thoughts [50].

2.3 Identity

Deep brain stimulation techniques provide welcome relief from treatment resistant depression, but ambiguous feelings about changes to patients' recognition of their sense of self, specifically related to aspects of their personality such as impulsivity, conscientiousness, neuroticism, openness, or agreeableness have been reported [51]. Consequently, these patients struggle to differentiate between neural device achievements and their own, which may create insecurities in their belief of their own abilities to overcome certain neurological disorders, and may the implanted device even be perceived as a "third party" or intruder in the patient's head [52], that competes, as opposed to enable control [53].

Another aspect to consider around the concept of identity involves the extension of a person's body and world by the addition of a neural devices that can be used by that person to control external objects such as robotic arms, wheelchairs or a computer cursor merely by "thinking" it into action with the help of the "intelligent" BCI [54]. This relationship between people and their devices requires closer investigation. Reiner et al. even considered whether technologies that extend the mind must be considered as new actors on the neuroethical stage, taking the intertwinement of modern humans with their surroundings into account, as well as the fact that the human brain can no longer be seen as isolated from a person's constant interaction with his or her environment [55]. These considerations will provide much needed insight into the existential question of what makes us human beings and how the impact of technology upon modern human beings may affect perceptions of what it means to be human. From a purely neuro-essentialist view, which define being human based on a person's neurophysiology, the connectedness to a BCI or others via BTBIs may potentially lead to a sense of communal self [56]. In this context and anticipating that in the future the transfer of emotions or memories (true or false) may be possible, the subsequent possibility that our own thoughts may be generated or owned by someone else which may further control how we act will have a huge impact on the development of an identity of oneself [57]. To date the effects of DBS on the self of the patient are still poorly understood and still need further and fuller phenomenological exploration of how patients respond to their neural implants, both in the short and long term, but is the growing evidence that an increasing number of patients experience postoperative neuropsychiatric changes indicative of real ethical concerns in this regard [58]. At this stage is it also impossible to predict whether the implantation of a BCI is the exclusive neurobiological cause of some of the self-estrangement effects reported by some patients, post-operative. However, it is noteworthy that in a tragic case in which a patient committed suicide, after receiving a DBS implant, the court found that postoperative changes were "more likely than not to have been due in significant but unquantifiable measure to the DBS" [59]. Further research into this phenomenon is important for the future acceptability of neurological technologies. How patients perceive themselves or experience self-estrangement after being implanted with DBS devices will largely dictate the acceptance rate of treatments using these devices.

2.4 Social equality

Cognitive enhancement can be achieved through a variety of methods ranging from nutritional supplements to brain stimulation [60]. The essence of enhancement or augmentation interventions is to "improve human form or functioning beyond what is necessary to sustain or restore good health", as opposed to treatment interventions which purpose is to restore a person to a "healthy" state [61]. But often the line between enhancement and treatment is blurred, because of cultural and social difference between what is considered to be "healthy" or "enhanced" [62]. For example, external or non-invasive techniques such as transcranial direct current stimulation (tDCS) showed both therapeutic as well as cognitive enhancing effects [63]. It can thus be anticipated that neurological technologies, that were initially designed for clinical treatment purposes, may later on be applied for its enhancing properties, as was the case with pharmaceutical cognitive enhancement products like treatments used for attention deficit hyperactivity disorder [64]. Daniels have argued that the distinction between the therapeutic or enhancing application of the same treatment matters ethically based on the legal obligation to provide medical care to people who need it, in contrast to merely enhancing perfectly healthy people [65].

Regardless of the difference between treatment and enhancement, the freedom to enhance, and if legally and socially acceptable, may create an obligation to provide equitable access to such enhancements and their benefits, which in turn poses various ethical dilemmas [66]. An analogy in this regard can be draw with the "non-medical" use of Adderall which highlighted demographic disparities, instead of providing equal opportunities to people who needs enhanced concentration [67]. This trend raises concerns that neurotechnological enhancers, considering the high costs of being implanted with a BCI or DBS, may also just confer or reinforce existing advantage or exacerbate educational, economic or other social inequalities [66].

Coupling brains by means of BTBI also harbours enhancement properties, especially when students use these technologies to increase their speed of learning or skill acquisition [68]. However, such facilitated learning could widen the gap of social inequities in education, and has the quality and long-lasting effects on knowledge retainment using this method of learning not been tested [69].

Finally, people's natural tendency to conform and survive will mean that they will be under pressure to adopt enhancing neurotechnologies, which will dramatically change societal norms and generate new forms of discrimination.

2.5 Hacking

Pantanowitz, the creator in the Brainternet, a brain-to-internet interface, has acknowledged that connecting everyone's brains to the internet could pose privacy and security issues like hacking [70]. The perk of being able to control your IoT with your mind soon fades away when faced with the reality that your mind may be hacked by a stranger with questionable motifs. This scenario many become even more problematic when researchers will enable the uploading of data to the brain, instead of just transmitting such data to the internet. Brain data that is connected to the internet is just as vulnerable as data contained in ordinary networks and can be stolen or released accidentally, thereby making it accessible to unauthorized and possible malicious parties. Neuro-applications, from Emotiv and NeuroSky, sold via so-called BCI "App Stores" already grant unrestricted access to its users' raw electroencephalogram (EEG) signals [71]. These applications also make users vulnerable to "brain spyware" that can extract confidential information using a BCI-enabled malicious application [72]. The prevention of unauthorized access to the information contained in brain data and protection of such data should enjoy the highest form of protection [73–75].

3 CONCLUSION AND RECOMMENDATIONS

Just as the field of genetics had to deal with its history of eugenics and earlier "brain science" in the form of psychosurgery had to manage its history of lobotomies [76], BCI technologies will similarly need to address ethical questions and concerns around the social acceptability, clinical safety and general allowability of emerging technological applications. But like lobotomies, BCI facilitated treatment may also be reached for as a so-called "last-ditch" medical therapy when a desperate patient is faced with few acceptable or effective treatments for mental illness or other disease, in which case BCIs, whilst still in its developmental phase and much like lobotomies, also be characterized by dubious consent, crude technique, lack of scientific evidence, and major side effects [77]. However, as history in this regard has pointed out, it is of critical importance to proactively address ethical issues as they arise, because so-called "last-ditch" medical interventions will probably always be prevalent. Adding the enhancement properties that BCI technologies can achieve in theory, we must scrutinize ethical concerns as they are conceptualized and not wait for incidents to occur, which may severely harm humans and their societies, and damage the future developments and refinement of BCIs and related technologies [77].

Accordingly, as our understanding of the human brain increases, we must continuously identify and address neuroethical implications of the application of any BCI technologies that will inform not only the trajectory of neuroscience research, but also the regulatory frameworks that will eventually govern the implementation of neuro-technologies. Currently no legislation exists that regulates informed consent or the protection of personal data extracted via BCIs, much less BTBIs. The Consensus Statement on European Brain Research only discusses biological techniques under the heading "emerging technologies" and makes no mention of any BCI interfaces or implantation of computerized technology [36]. There are also no formal protocols that provide guidance for how research must be conducted when using these technologies [78]. Moreover, there is no single constitution for the digital ecosystem with which BCIs are to be connected, and can the principles of contemporary constitutionalism such as democracy, rule of law, and the separation of powers not simply be transplanted into this digital ecosystem without due consideration of its very unique challenges as described above. Although the very nature of constitutionalism, being its goal to protect fundamental rights, remains relevant, it is the idea of constitutionalism with a nation state that poses problems for the governance of fundamental digital rights. Subsequently, existing constitutional principles and fundamental rights need to adapt to the changing needs of individuals who find themselves increasingly merged with technology, be it via BCIs or other. This paper does not pretend to pose effective answers to these complex issues, but wishes to highlight some of the aspects of fundamental rights that needs particular consideration when working towards the articulation of fundamental values into a novel constitutional governance to guide the development and implementation of BCIs.

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