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RESEARCH BRIEF
THE EVOLVING NEUROTECHNOLOGY LANDSCAPE: EXAMINING THE ROLE AND IMPORTANCE OF HUMAN RIGHTS IN REGULATION

EXECUTIVE SUMMARY

Neurotechnology – electronic devices or methods used to read or modify neural activity[2] – is transforming the lives of individuals affected by paraplegia, neurological conditions and mental health disorders. Such gains have been enabled, at least in part, by the emergence of the private sector as a developer and retailer of neurotechnology. Indeed, the scale of investment – around USD 32 billion[3] – has fast-tracked innovation and allowed the breaching of cost watersheds.

A further offshoot of private sector engagement has been the development of neurotechnology for non-therapeutic and consumer purposes, including brain-monitoring 'headware', neuro-enhancive devices and mind-controlled recreational products. Again, there are huge benefits to be reaped. The ability to harness, read and interpret brain signals offers pathways to improve public safety, lift workforce productivity and find solutions to global challenges such as food insecurity and climate change. But there are also risks. These include direct externalities (violation of the rights to privacy, property, freedom from discrimination etc.) and indirect externalities (spillovers for social cohesion, inequality and inter-group tolerance).

Such concerns have brought questions around how to regulate neurotechnology, at the domestic, regional and international levels, to the fore. Indeed, the vast incentives to develop neurotechnology – for legitimate and non-legitimate means – underscore both the importance and complication of crafting a common framework grounded in minimum standards and human rights. Chili was the first country to take active steps in 2021, its senate passing a bill to amend the Constitution to protect brain rights. In late 2022, the UN Human Rights Council adopted resolution A/HRC/51/3, requesting its Advisory Committee to prepare a study examining the human rights implications of neurotechnology. Most recently, in May 2023, the UN Secretary General's Technology Envoy announced the formation of a high level working group charged with examining the regulatory challenges posed by, inter alia, neurotechnologies.

As these efforts gain pace, various challenges have been encountered. A first concerns bringing together scientists, commercial actors, human rights experts and policy makers – communities of practice that use different vocabularies, have different worldviews and pursue different visions of success. A related issue is that confusion around neurotechnology – what it can, might and cannot do – has stoked a climate of alarmism. This has, in turn, diverted attention away from extant risks and how to strike a balance that enables innovation and protects rights.

In response, this paper provides a backdrop against which some of the more complex tensions around regulation might be reconciled. Part 1 explains the evolution of neurotechnology, the role of the corporate sector, and why this concerns some stakeholders. Part 2 discusses four rapidly emerging neurotechnologies, including their limits, future potential and possible externalities in the areas of human rights, social cohesion and conflict. The final section sets out a framework against which to consider regulation and offers insight on the role that human rights might play in this.

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KEY RECOMMENDATIONS

Debates need to home in on extant risks

It is important that regulatory debates distinguish between what neurotechnology can currently deliver, and what might be delivered in the future. Equally, there is a need to distinguish between externalities that demand an ethical analysis, those that might encroach upon human rights, and externalities that require regulation because they are socially harmful. Conflation between these areas can divert attention towards alarmist scenarios and crowd out discussions on how to most effectively regulate extant and near-term risks.

Applying a political lens to 'neurorights'

Debates on whether the existing human rights framework is sufficient to protect against the negative externalities posed by neurotechnology need to be viewed through a lens of political pragmatism. Indeed, one symptom of today's deep polarization and reduced confidence in the multilateral system is a limited appetite for the expansion of existing rights, or the creation of new ones. In this context, a push for 'neurorights' might be met with a lukewarm response, or even collective dismissal. This might problematize and/or delegitimize attempts to then invoke existing human rights as a bulwark against the risks posed, potentially resulting in an erosion in the overall level of protection enjoyed.

Human rights as a key part of the regulatory solution

Domestic law and regulation is currently the most effective framework to protect individuals from the risks posed by neurotechnology. Human rights will be an important tool through which to craft such rules. However, the incentives to develop neurotechnology – both for legitimate and non-legitimate means – are such that the uptake of a common framework grounded in minimum standards is unlikely. Strong national legislation will thus need to be complemented by import laws and other trade controls, laws around enabling technology such as AI, corporate self-regulation and arguably some form of supra-national oversight mechanism that can monitor industry, non-state groups, and states themselves.

Equality of access is key

Advances in neurotechnology offer huge potential gains, including in the detection and treatment of neurological conditions, improvements to public safety and workforce productivity, and even identifying solutions to global challenges. If, however, such gains are only made available to the rich or in certain countries or groups, inequality may be exacerbated, which will have knock-on consequences for a range of human rights, as well as other socially undesirable ends such as conflict. While this is not a feature of the technologies, but instead systems of inequality revealed by the technology, equality of access must sit at the fore of regulatory discussions.

Regulation will need to incorporate a trade component

With the technical capacity and resources to develop neurotechnology independently, it is inevitable that some companies will take advantage of digitalized technologies' ease of transfer and the integrated nature of globalized economy to strategically locate in whichever regulatory environment offers the fewest restrictions. This particularly concerns entities pursuing malign ends or wishing to sell their products on unregulated markets. To mitigate against this national regulation should introduce specific measures to restrict the import and export of dangerous neurotechnologies.

Regulating the unregulated

The market for non-invasive 'brainware' that can monitor neural activity is growing rapidly. These products are not enhancive in that they do not interfere with neural connections; instead, they provide a brain data 'readout' that can be interpreted and acted upon. To the extent that such products are presented as 'wellness devices', companies can largely sidestep regulatory controls around testing, risk evaluation and ethics review. As brainware devices becomes more sophisticated, their classification may need to be reviewed.

Untangling digital technologies

A key challenge in regulating the development and sale of neurotechnology will be unpacking how neurotechnology interacts with other digital technologies – particularly artificial intelligence. A critical part of the regulation-setting process with thus be identifying when a malign human rights outcome is not due to the neurotechnology, but a technology underpinning it.

The challenge of setting 'red lines' around neurotechnology

While the possible misuses of neurotechnology speak to a logic of strict regulation, where such lines should be drawn will likely be contested. One issue will be reaching agreement on how to maximize positive innovation while minimizing negative externalities. Another point of potential misalignment will be drawing lines between what is acceptable and unacceptable interference in human decision-making, thoughts and emotions. Ethicists, psychologists/psychiatrists, behavioral scientists, neuroscientists etc. will prove be critical voices in these conversations.

1. THE EMERGENCE OF THE CORPORATE NEUROTECHNOLOGY SECTOR

NEUROTECHNOLOGY: FORMS, FUNCTIONS AND DEFINITIONS

Neurotechnology broadly refers to any electronic device or method that can be used to read or modify human neural activity.[4] These technologies generally fall into two categories, both of which can have implanted (e.g. brain implant) and wearable (e.g. skull cap, neural imaging) applications. First, where an external system modulates brain activity, for example by applying electrical currents, to achieve a desired result such as halting a tremor. Second, where an external system recognizes specific patterns of brain activity and translates them into technical commands such as text or movement. These technologies were developed and exist principally for medical and therapeutic ends, however recreational, lifestyle and enhancement applications are increasingly feasible and commercially available.

HOW PRIVATE COMPANIES ENTERED THE NEUROTECHNOLOGY DEVELOPMENT SPACE?

The exponential advancement of neurotechnology over the past decades has pushed it to the forefront of scientific, ethical and political debates. Such debate is focused, not only on what neurotechnology can do, but also who is doing it — particularly how the corporate sector has penetrated and positioned itself in what was once a small and highly regulated medical space.[5]

The explanation is simple but instructive. Pre-millennium, the complexity and expense of engaging in neurotechnology confined it to small pockets of medical research in developed countries. Three transformations have challenged this status quo. First, expanded medical application coupled with improved brain mapping tools (particularly the of use deep brain implants and neuroimaging) resulted in a vastly enlarged pool of data by which to collect, code and interpret neural activity, and thus a more sophisticated and accurate mapping of movement, emotion and decision centers. The second transformation was advances in machine learning and its application, particularly to BMI. By automating much of the necessary computation-translation and integrating algorithms that anticipate user intention, the speed and accuracy of neural interfaces improved significantly. Machine-learning algorithms also enabled better filtering of 'noise' to improve the signal from wearable brain sensors. Together, this transformed BMI from slow, expensive and bulky technology, into systems that were increasingly functional and user friendly.

NEUROTECHNOLOGY TYPOLOGIES

External system brain interference

These neurotechnologies target specific areas of the brain with electrical currents or ultrasound to regularize neural activity, or stimulate or inhibit neural circuits. These treatments, which include Deep Brain Stimulation,[6] Transcranial Magnetic Stimulation[7] Transcranial Direct Current Stimulation[8] and Focused Ultrasound,[9] are used to treat conditions including epilepsy, Parkinson's and Alzheimer's disease, improve stroke recovery and relieve chronic pain.[10] The technology can also be used diagnose and treat mental illness, such as Obsessive Compulsive Disorder, depression, anxiety, addiction, Post-Traumatic Stress Disorder and Attention Deficit (and Hyperactivity) Disorder.[11] In healthy patients, future applications of the technology may include behavior modification, accelerated learning and enhanced task performance.

Brain machine interface (BMI)

Through these neurotechnologies, an external system receives and recognizes specific patterns of brain activity, then translates them into technical commands such as text, movement or a decision.[12] The application of these technologies has until now been primarily for therapeutic purposes, for example allowing individuals affected by Amyotrophic Lateral Sclerosis (ALS), cerebral palsy, stroke or spinal cord injury, to move a cursor, type or use a prosthetic/wheelchair using their mind. Increasingly, commercial applications of these technologies are being developed and marketed to allow individuals to monitor mental focus; for recreational 'neuro-gaming' and neural-interface such as mind-operated smart phones and remote controls.

Neuro-prostheses

Classified as neurotechnology but operate using different technology. Examples include the cochlear hearing implant[13] and artificial retinas.[14] These devices detect sensory – noise, visual or touch – stimuli from the environment which is then transmitted to the nerve responsible for relaying this information to the brain. In the case of damaged nerves, a variation of this technology can relay sensory data directly to the brain through a microprocessor, for example to recreate touch sensations in patients with spinal cord injuries.

Third, the growth of multi-functional wearable devices and the ability to miniaturize and embed sensors into those devices have addressed the 'form factor', increasing the integration of brain sensors (primarily EMG and EEG sensors) into smart devices including watches, ear buds, headphones, headbands and hats.[15]

More sophisticated neural mapping coupled with the progress enabled by machine learning and form factor improvements meant that a technological — and therefore cost — watershed was breached. The corporate sector quickly realized that this expanded the scope of market opportunities for neurotechnological applications.[16] For example, an aging population implied an increase in neurogenerative disorders such as Parkinson's disease, Alzheimer's disease, ALS and stroke and thus the number of persons who might benefit from BMI devices.[17] Neurotech treatments for mental health and psychiatric conditions — estimated to cost the global economy USD 1.5 trillion annually[18] — offered another entry point. Third, companies identified a potential for recreational and lifestyle applications, such as wireless headsets that decode brainwaves allowing users to play games ('neuro-gaming') or operate mind-command smart appliances such as phones or televisions. Finally, business applications such as 'thought-to-text' computer programs, automated 'in-brain' language translation and 'thought sharing' offered new scope for productivity gains and cost savings.

THE RISKS ASSOCIATED WITH A PRIVATIZED NEUROTECHNOLOGY SECTOR

The concern around corporate entities entering the neurotechnology space has two elements. The first is how the advanced state of brain mapping and decoding knowledge — which accrued incidental to the development of medical applications — might be misapplied. As expanded in box 1 below, neurotechnology has a type of 'dual use' potential, in that developers can apply the same circuit identification, coding and manipulation methods, but to achieve a malign result. This creates myriad risks, including in the areas of human rights (protection of privacy, freedom from discrimination, freedom of thought, self-determination etc.), social cohesion, conflict spillovers and weaponization. Moreover, it begs questions around whether companies — and by extension their consumers, which might include authoritarian states, non-state armed groups, private military and security companies, fringe political parties and organized crime networks — should exercise this type of power and decision-making.

The second issue is the paucity of existing regulation and challenges around extending such regulation. In the pre-millennium period, the development of neurotechnology was relatively simple to monitor and control. The sector's small footprint and reliance on government financing confined it to economically advanced countries which typically had strong governance and comprehensive regulatory frameworks. With little scope for misuse, regulation, guiding standards and ethical safeguards did not evolve in a manner that has kept pace with technological development.

Crafting and rolling out a more robust regulatory framework, however, will be extremely challenging. Today's corporate neurotechnology sector is large, mobile, and the enormous scope for profits has kick-started a race to lead on innovation. Individual states likewise have incentives to develop neurotechnology — as a high growth export sector, a pathway to increase domestic productivity, to address the needs of an aging population, and as tool of military protection. These competitive forces and vested interests mean that domestic regulation will likely evolve in a patchy manner. At the same time, global minimum standards — ones that adequately balance innovation and individual protection — will be difficult to broker, and international human rights law (another potential pathway) suffers from constraints around enforceability.

To unpack these issues, the following section discusses how the principal neurotechnologies have evolved, their current (and potential future) application, and the potential negative externalities through a human rights lens.

HOW ADVANCES IN NEUROTECHNOLOGY MIGHT BE MISUSED

A principal application of neurotechnology is the treatment of debilitating medical conditions by using electrical currents to modulate, stimulate or immobilize specific neural circuits. For example, epileptic seizures can be managed through electrodes that stimulate the anterior nucleus of the thalmus – the brain station that controls and coordinates muscle activity. Identifying the neural circuitry responsible for epilepsy was a complex process; the brain is composed of 86 billion neurons, each of which have around 10,000 connections, making the potential number of circuits almost infinite.[19] Pinpointing specific circuits related to specific conditions thus took place in the context of a wider neural mapping process. The upshot is that the methodology that enabled scientists to target the brain circuitry responsible for epilepsy, also set out the neural circuitry responsible for other tendencies, including ones that could (in theory) be manipulated for malign purposes (violence, narcissism, racism) and enhancive ends (cognition, attention and memory).

Neurotechnology's other principal application is the BMI, which works by recognizing a pattern of brain circuitry and translating it into technical commands that can be functionalized by a computer program or robot. This is the technology that allows a quadriplegic to 'think' a movement (that is then carried out by a cursor), a response (that is transformed into soundwaves and verbalized by a computer) or an instruction (for example turning on an appliance). Again, because each thought corresponds to a unique neural circuit, the process of decoding patterns of brain activity needed to take place on a meta-level using machine learning. A similar consequence accrued: the methodology that allowed a computer to decode one (innocuous) human thought could potentially be applied to decode a far wider range of (sensitive or private) thoughts. If in the future these technologies become more reliable and less invasive, risks include breaches of thought privacy (thoughts being read remotely without consent), thought ownership rights (whether decoded thoughts belong to the individual or the owners of the decoding technology), thought theft (for commercial or security ends) and the misuse of thought metadata (for marketing or political purposes).

2. SCIENCEFACT OR SCIENCEFICTION?

AN EXAMINATION OF EXISTING NEUROTECHNOLOGIES THROUGH A HUMAN RIGHTS LENS

As the discourse on the risks associated with neurotechnology expands, it is critical to distinguish between what neurotechnology can currently deliver, and what might be delivered in the future. While there is some overlap, it is equally important to distinguish between externalities that demand an ethical analysis, those that might encroach upon human rights, and externalities that require regulation, not because they breach human rights but are because they are socially harmful. To date, conflation between these areas, together with a focus on alarmist risks such as consumer products with mindreading and brain hacking capability, has somewhat crowded out discussions on how to best regulate extant and near-term risks. In response, this section sets out four rapidly advancing neurotechnologies, what they can and cannot do under current science, and the potential concerns they raise.

NEURO-MARKETING

In 2002, the market for consumer research generated revenues in excess of USD 81 billion. Despite this investment, the dominant methodologies — interviews, surveys and big-data analytics — remain imprecise and error prone. In large part, this is because purchasing behavior does not follow a discernable logic; consumers do not always know why they preference a certain product and the link between preference and purchase is not always direct.[20] To close this knowledge gap, companies have begun to use electroencephalography (EEG) and functional medical imaging techniques (FMRI) on test groups of consumers to measure how specific neural networks — for example those associated with receptivity or desire — react when a product is viewed or touched. This data can then be used to craft content, products and advertising.[21] The technique is being used by entities as diverse as NBC, Warner Bros., Ikea, all the way through to humanitarian organizations. The Italian office of the UN High Commissioner for Refugees, for example, tested different advertising content on participants wearing EEG devices to understand which 'call to action' evoked the greatest empathy and thus response (in this case a financial donation).[22]

Employing techniques drawn from neuroscience to make branding more effective is unlikely, ipso facto, to encroach upon human rights as an individual's freedom to exercise choice is not impacted. These practices signal what consumers respond to; they do not manipulate an individual's preferences or proclivity to purchase. As such, neuro-marketing might be understood as a more sophisticated iteration of traditional advertising. Moreover, the logic underpinning marketing may not be something policy-makers should seek to regulate. As scholar Farahany highlights, action aimed to influence, convince or cajole is a normal, accepted and arguably important dimension of human behavior that would be problematic — both from a practical and ethical standpoint — to legally restrict.[23]

This is not to say that neuro-marketing is never harmful, nor that some level of regulation is unwarranted. A particularly malign situation is when insights gained from EEG or FMRI testing are combined with other digital technologies, particularly Artificial Intelligence (AI). As discussed in section 2.3 below, weak regulation coupled with society's increased dependence on the internet for news, communication and the exchange of goods and services has resulted in platform owners gaining unprecedented access to user data, including on income, purchase histories, beliefs, relationship status, vulnerabilities etc. This data can be sold to retailer and advertising companies, who use AI optimization algorithms to push content and products. The result is highly customized marketing that draws on multiple dimensions of an individual's personality, circumstance and inclinations. [24]

Similar arguments can be levelled against the development of deliberately habit-forming software that works by invoking innate neural responses such as the need for social reciprocity. This mainly concerns social media and entertainment companies; examples include Snapchat 'streaks', LinkedIn/Facebooks's 'likeable' units and Netflix's episode 'autoplay'.[25] As this type of neural-addiction becomes better understood, human rights arguments might be leveraged, not dissimilar to approaches pursued to regulate tobacco marketing and protect non-smokers from third party exposure.[26]

NEURO-ENHANCEMENT

Neuro-enhancement generally refers to implanted or semi-implanted devices that replace, augment or substitute a human sense or ability. Such technologies have vastly improved the quality of life of individuals affected by stroke and hearing loss, with quadriplegia, and suffering from neurological diseases such as ALS.[27] Many will have heard of, for example, Mark Pollock who in 2012 became the first person to own a robotic exoskeleton,[28] and quadriplegic Rodrigo Hubner Mendez who in 2017 used his mind to drive a formula one racecar.[29] It is envisaged that the next leap will be speech neuro-prosthetics — 'thought-to-text' devices that can restore the power of communication to victims of stroke, anarthria and other forms of paralysis.[30]

PRIVATE COMPANIES AS DEVELOPERS OF MEDICAL NEUROTECHNOLOGY

Gains in the medical sector have undoubtedly been fast-tracked by private sector engagement as both a developer and retailer of such technologies. In 2019, the Synchron-patented 'stentrode' was trialed in five patients with neurogenerative disorders allowing them to order groceries, email and text using their minds.[31] Control Bionics has pioneered similar BMI technology that allows ALS suffers to operate tablets and motor devices.[32]

Such innovations beg questions around whether and in what circumstances enhancements should be made available to healthy individuals. Here, it is important to distinguish between experiments taking place in clinical/research settings, and commercially available neuro-enhancive devices. With regards to the former, the level of advancement is indeed sophisticated. In 2022, Coventry University's Kevin Warwick had a microelectrode array implanted in his arm, the wires from which connected to an external connector pad with a computer interface. He was able to then transmit neural signals from his nervous system to the computer, and reciprocally, the computer could send signals to his brain through nerve fibers. The upshot was that Warwick was enabled to sense ultrasonic waves, much like a whale.[33] While such technologies give rise to important ethical and rights-based questions, it is important to underscore that they are a far distance from commercialization.

Less invasive neuro-enhancive tools, however, have reached the work and marketplace. In 2018, Ford Motors introduced the use of 'exoskeletons' which transfer human muscle load to a robotic upper-body attachment, thus improving productivity and reducing the risk of injury.[34] Another market-ready enhancement tool is Transcranial Direct Current Stimulation (TDCS) — headsets that deliver small electrical currents which stimulate or arrest the firing of neurons. The result is a heightened state of brain plasticity, effecting improved attention, cognition, learning and performance.[35] TDCS technology was crafted as a military tool more than 20 years ago,[36] but its use has since expanded to athletes, musicians and academics. A final neuro-enhancive tool is nootropics — synthetic drugs that improve cognitive function such as processing speed and memory. Most nootropics (such as Adoral and Ritalin) were originally developed to treat neurological and mental health disorders, however there is a burgeoning market for products offering bespoke outcomes,[37] with the industry expected to grow to USD11.6 billion by 2024.

Whether neuro-enhancement should be permitted, when and in what contexts, has principally been debated as a question of ethics. The conservative view is that enhancement is a risk to human dignity, identity and even existence "because it may produce undesirable physical and social changes in human beings".[38] The counterargument is that neuro-enhancement is a fundamental component of the human story, observable throughout history,[39] including in our development of language, institutionalized education, and use naturally occurring nootropics such as ephedra, caffeine and bacacopa.[40] Similar to neuro-marketing then, enhancement should be viewed as a more impactful means of achieving what is already accepted as a legitimate practice for a positive end. Similarly positioned scholars favor neuro-enhancement from a public utility standpoint. Farahany, for example, applies this reasoning to support enhancing — not only certain professionals, such as surgeons, scientists and pilots — but also to benefit society more generally. She posits that "[l]ife is not a zero-sum game, and cognitive enhancement in everyday life stands to benefit everyone by lifting us up as a whole".[41] The complication with this logic, she admits, is how to ensure equality of access. If neuro-enhancive technologies are available only to the rich or in certain countries or groups, inequality may be exacerbated, which will have knock-on consequences for a range of human rights, as well as other socially undesirable ends such as conflict.[42] Importantly, this is not a feature of the technologies, but other systems of inequality that are revealed by the technology. Another risk is that broad access to neuro-enhancement creates a 'race to the top'; it is possible to imagine scenarios where enhancement prerequisites an individual's employability, creates discreet spheres of social interaction and/or limits participation in certain types of leisure or cultural activities.[43]

BRAIN MONITORING, SURVEILLANCE AND DECODING

An important consequence of private companies entering the medical neuroscience space is their leveraging of proprietary technology to develop spinoff commercial products such as neurogaming, mind-operated lifestyle appliances, and business applications. To date, the most widely sold device is EEG headsets, which offer an inexpensive and non-invasive means by which to monitor brain activity. Retailers market such 'brainware' as tools to track attentiveness and thus identify the external conditions that enable users to maintain the highest state of cognitive functioning.[44] These products are not enhancive in that they do not interfere with neural connections; instead, they provide a brain data 'read-out' that can be interpreted and acted upon. Tan Le, the

NEURO-ENHANCEMENT AND HUMAN RIGHTS IN A NUTSHELL

When it is safe and fully consensual, neuro-enhancement is unlikely to violate an individual's human rights. Broad access to neuro-enhancement, however, triggers specific rights-based questions, and has the potential to create societal spillovers including in the area of human rights. Consider the following hypotheticals:

Should a surgeon/attorney who discontinues the use of a neuro-enhancive technology be required to disclose this, or does his/her right to privacy trump their patient/client's right to information that concerns them?

Could employers — explicitly or implicitly — mandate the use of enhancive technologies?

Could broad access to neuro-enhancement create a new iteration of discrimination between the neuro-enhanced and non-neuro-enhanced?

founder of neurotech company Emotiv, posits that in the future, real-time EEG data flows will seamlessly interact with workplace features, automatically adjusting light, music and temperature, to allow users to stay in or return to 'the zone'.[45]

Few would question the utility of such a tool, especially for workers where cognitive alertness is essential, such as vehicle and machinery operators, military decision-makers, surgeons etc.[46] There are, however, concerns — principally whether workplaces might attempt to require such monitoring, and if so, whether the gains in public safety and productivity would justify the encroachment on individual privacy. Indeed, in China, high speed train drivers have to wear EEG headsets to monitor fatigue, and there is anecdotal evidence that the same has been trialed in government-owned factories and schools.[47]

It is important to consider such questions against what is an evolving context. Independent of neurotechnological advancement, the last two decades has seen a steady trend in companies surveilling employees. Examples include Tesco and Amazon introducing digital armbands, through to automatic computer screenshotting that allows employers to monitor the content a worker is producing, viewing or interacting with.[48] This has been enabled by weaknesses in the regulatory framework across jurisdictions. Farahany explains that most countries, in both the global north and south, favor contractual freedom, meaning that as long as employees agree to being monitored, the law confers few restrictions. She gives the example of Europe's General Data Protection Regulation (GDPR) which allows monitoring insofar as companies have a 'legitimate' reason. Such flexibility, coupled with power imbalances between workers and employers, create a context where an individual's brain data might be used punitively, exploitatively, or sold to third party data brokers.[49]

The question of who controls and can access collected brain data — individuals, their employers, or the owners of the technology that translates neural signals into usable data — is at the fore.

The more widely debated risk is that companies and/or governments further develop these brainware devices to include mind-reading or hacking capabilities. The science behind this concern is that EEG devices operate on the basis of detecting, reading and recording raw neural data. This neural data is unique — more so than a fingerprint.[50] It follows that if brain-decoding technology advanced to a point where it could be reliably and cost-effectively integrated into non-invasive devices, this might be used to both identify an individual, and uncover their privately held knowledge, beliefs, preferences and biases. Such information could be used for legitimate ends, such as criminal investigation and prosecution (see box 5), preventing terrorism, or a safer and more efficient 'brain-biometric' approach to making purchases, banking, passport control etc. But it also creates scope for such information to be exploited by commercial enterprises (retailers, advertisers, financial brokers, insurers etc.), or for politically malign purposes (surveilling, preventing protest or targeting opposition figures).[51]

HOW CLOSE ARE WE TO BRAIN-DECODING?

Every human thought, movement or action creates a unique pattern of neural network activity. Such activity produces electrical waves oscillating at different frequencies that can be read by technologies including EEG and FMRI.52 Using machine learning to interpret large sets of such 'brain data', it has been possible to identify neural patterns that correlate with specific words/utterances, cognitive states, commands and emotions. In 2008, Carnegie Mellon University's Professor Marcel Just twinned brain imaging with machine learning to predict categories of words and numbers 'thought' by research subjects.53 In 2014, a research team at the University of Washington successfully piloted a tri-person 'brain-to-brain' communication facility enabled by BMI.54 Outside of laboratories, however, this technology remains inconsistent and error prone. Challenges include that EEG headsets can only detect faint brain signals, the difficulty distinguishing between simultaneously occurring brain circuitry, and the fact that neural patterns are highly individualized. Taken together, such challenges mean that 'brain reading' is unlikely to be available commercially or possible through non-invasive lifestyle devices for many years.55

When assessing these risks, it is important to draw lines between the current state of research and its market-readiness. Indeed, when Neuralink posted its video of a monkey playing the computer game Kong with its mind in 2021, it fueled speculation that the company was on the brink of developing implants with brain-data downloading, uploading and sharing capability.[56] The reality, however, is that 'brain-reading' science remains in its infancy and is largely limited to laboratory settings (see box 4). Moreover, such scenarios are dependent on a number of assumptions being borne out. Principally, EEG-enabled devices would need to be mainstreamed — worn at home, work and school in the same way we carry smart phones, but with far greater functionality. Another assumption is that headset-users readily give up their brain data to the platform/algorithm owner. If current norms hold, this risk should not be dismissed. Three trends are noteworthy. First, a vast majority of internet users 'accept' cookies or default settings as they do not have the inclination or skills to 'manage' them. In doing so, users pass on a vast quantities personal data, including their search histories, previous purchases, contacts etc. The extent of this problem was showcased in 2020, when the company 23andme provoked widespread condemnation for selling the data of 10.7 million users which it had acquired through default setting.[57] A second trend is the 'technologization' of modern society. As more everyday functions — shopping, communicating, working, voting, accessing entertainment — become web-based, individuals are increasingly bound to the internet, and thus the choice not use certain platforms is increasingly limited. Third, as competition grows platform owners offer incentives, for example trading access to a users' browser data for faster internet, access to free digital services or larger download capacity. This combination of capacity, necessity and incentives place the companies that own platforms in a strong position of power, potentially ushering in a new era of what Shoshana Zuboff has termed 'surveillance capitalism'.[58]

Companies such as Facebook, LinkedIn, Google and Amazon have gained almost unfettered access to data on user preferences and other identity markers. This has served as a basis to push content on users, to sell products, influence elections, propagate racially motivated violence etc.[59] If companies also gain access to neural data the risk is a new era of 'surveillance capitalism' where data on thoughts, feelings and beliefs become subject to commodification, monetization and control.[60]

NEUROTECHNOLOGY AS A TOOL FOR CRIME PREVENTION AND INVESTIGATION

The advanced state of brain mapping research has uncovered certain neural frequencies that can be applied almost like a 'thought polygraph' to pick up on involuntary internal utterances. For example the P-300 'recollection' frequency might be used to assess whether a suspect recognizes a victim, weapon or other piece of evidence; the N-400 'congruency' frequency might be used to assess if a suspect approves or disapproves a set of data parameters that are consistent with a particular crime. There is evidence that some states are using variations on such technology to interrogate suspects in criminal investigations. This raises important human rights law questions. Should suspects be able to deny access to brain data by invoking the right to protection against self-incrimination enshrined in ICCPR 14.2.g? Or would such data be deemed physical evidence, to which such rights do not apply? Or could brain data be deemed the property of the internet platform/algorithm owner (which might be a government) and thus subject to the power of subpoena?[61]

WEAPONIZED NEUROTECHNOLOGY

Building on brain mapping and decoding science, a final risk is weaponized neuro-hacking or neuro-manipulation. While it is clear that some militaries have engaged in such research, since as early as the 1950s, there is no reliable evidence on the current state of these technologies between countries.[62] It is possible, however, to imagine a weaponized form of existing neurotechnologies, for example that stimulate or arrest specific neural networks to obtain a malign result.[63]

What can be said with more certainty (and indeed is the more likely near-term scenario) is that future wars will be digital, and will include neurotechnological components such as cognitive controlled/BMI weapons and soldier enhancement.[64] To date there has been little inquiry into how robust a framework international humanitarian or human rights law will prove against such developments. Perhaps more fundamental is how digital technologies have the potential to modify the nature of armed conflict insofar as victory/defeat becomes a question of technological superiority, thus removing the determinative role of military tactics, law, resources, popular opinion, soldier morale etc. While such outcome predictability might reduce the death and destruction caused by war, such revised 'rules of the game' may broaden the incentive/scope for illegal encroachments on state sovereignty, illegal annexations or coups.

KEY RISKS ASSOCIATED WITH NEUROTECHNOLOGY

Explanation of risk	Extant risks	Potential future risks
Interference in cognitive liberty and mental agency[65] Insofar that neurotechnology can tap into decision-making, positioning and impulses, it threatens the ability of individuals to govern their own behavior, relationships and trajectory.	▪ Neuro-market research conducted, or the data sold, without consent. ▪ Neuro-marketing targeting vulnerable groups such as children. ▪ Algorithms configured to addict for the overall purpose of enhancing sales.	▪ Companies combining neuro-marketing research with other neurotechnologies to compel specific consumer choices. ▪ State or non-state groups 'switching on' neural circuits that control anger, violence, criminality or racism, with a view to provoking unrest, staging coups, determining election outcomes, etc. ▪ State or non-state groups 'switching on' neural circuits that control compliance or passivity to facilitate extractive or exploitative practice, human rights abuses or repression. ▪ Weaponized neurotechnology used by state and non-state actors, terrorist groups or organized crime networks to control their operatives' decision-making, inhibition, risk analysis and malleability.
Mental privacy and 'brain-hacking' The scope for an electronic system to identify and decode an individual's thoughts, emotions, preferences and proficiencies creates risks around privacy, ownership, exploitation, data protection.	▪ Compulsory workplace/school brain monitoring. ▪ Brain data collected in the workplace being sold to third party data brokers. ▪ The publishing of anonymized brain data being linked to the owner.	▪ The identification and targeting of persons based their religion, sexual preference or political opinion. ▪ In jurisdictions that criminalize acts, for example sex outside of marriage, apostasy or homosexuality, brain-hacking could facilitate an expansion of sanctions that violate human rights. ▪ The incarceration of persons with homicidal, criminal, or violent intent outside of a judicial process. ▪ The brain-hacking of ideas and thought theft undertaken for the purpose of exploitation, or for commercial, political or security ends. ▪ The use of brain analysis to facilitate educational or vocational 'streaming', resulting in unequal access to education and livelihoods, reduced vocational autonomy, or forced labor/vocational slavery.
Brain alterations and self-determination[66] The use of neurotechnology to improve attention, cognition, memory and problem solving has the potential to deepen inequality (between and within countries), expand the forms of discrimination and creates scope for human neuro-engineering.	▪ Compulsory use of brain-altering/enhancement technology in the workplace. ▪ Device error, malfunctioning, provider redundancy. ▪ Unequal access exacerbates societal inequalities.	▪ Companies or states compelling neuro-engineering as a means of developing a more effective and efficient workforce, sporting figures or military force. ▪ Unequal access to enhancement technology resulting in 'super-classes' or 'super-countries'.

3. TO RIGHT OR NOT TO RIGHT?

CRAFTING A FRAMEWORK FOR SAFE NEUROTECHNOLOGICAL ADVANCEMENT

Advancements in neurotechnology have turned it into somewhat of a 'dual-use' item, insofar that innovations originally developed for medical application have been repurposed to create spinoff commercial devices and applications. Pivotal to this has been the emergence of the private sector as an investor, developer and retailer of both sets of products. Indeed, the market for neurotechnology is growing at 12 percent annually and is expected to reach USD40 billion by 2026.[67] And it is understandable why — neurotechnology promises an aging population improved health and autonomy, businesses improved efficiency and productivity, and — for the technologically savvy — a wider array of tools by which to communicate and enjoy entertainment. Such private sector engagement is by no means a bad thing. It has undoubtedly accelerated the pace by which therapeutic devices have reached the consumer market, and it may provide a pathway to craft solutions to global challenges such as climate change. Such engagement may also prove a prerequisite if neurotechnology is to act as an equalizer between the global south and north, for example in the detection and treatment of neurological and mental health disorders.

At the same time, neurotechnology's expansion outside of what was a highly regulated medical space has — and will increasingly — impact the functioning of societies and typologies of human interaction. These changed 'rule of the game' create potential for negative spillovers, some of which are predictable (unemployment in certain sectors) and others unpredictable (how reduced social contact may impact inter-group tolerance). These risks are also multifaceted, including violations of human rights, diminutions in social cohesion, exacerbated inequality between and within countries, and violent conflict. The most serious concern is that existing neurotechnologies will be reconstituted for malign ends — to incite violence, exploit vulnerable groups, manipulate democratic processes or exercise military prowess. While such threats are often exaggerated in the media, a level of cautious anticipation is prudent. The growing potential of AI and its applications such as machine learning and generative AI mean that watershed moments will arrive faster and more frequently.

These concerns have brought debates on how the development and sale neurotechnology might be regulated to the fore. The majority of this discussion has taken place through a lens of ethics. In 2015, the OECD's working party on Biotechnology, Nanotechnology and Converging Technologies launched a project to elaborate a framework for the responsible development, integration, and use of new and innovative neurotechnologies for health-related applications. In 2019, it approved a 'Recommendation on Responsible Innovation in Neurotechnology' listing nine key principles. A set of practical tools and guidance on the implementation of these recommendations is set to be released in 2023. UNESCO's International Bioethics Committee is another significant actor. In 2019, it established a working group to investigate and reflect upon advancements in neurotechnology and in 2021 released its first report focused on ethical challenges.[68]

More recently, these debates have widened to include the implications of neurotechnology on human rights, and the role that human rights might play in regulation. This commenced in 2021, with discussions at both the Council of Europe and the Interamerican Commission of Human Rights.[69] In late 2022, the UN Human Rights Council adopted resolution A/HRC/51/3, requesting its Advisory Committee to prepare a study examining the human rights implications of neurotechnology to be presented at its fifty-seventh session 2024. Most recently, in July 2023, UNESCO's International Bioethics Committee released a report on the risks and challenges of neurotechnologies for human rights.

At the center of this latter debate is whether the current human rights framework is sufficient to protect individuals against the negative externalities posed by neurotechnology. Scholars such as Rafeal Yuste advocate the recognition of 'neurorights', either by 'upgrading' existing law or creating a new international convention[70]. Farahany argues for a new human right to 'cognitive liberty', alongside the creation of enforceable global norms that can direct the updating of existing rights to privacy, freedom of thought, and self-determination.[71] An alternate, but potentially complementary, view is that existing rights — including to freedom of opinion, freedom of thought and the right to privacy — provide the necessary basis for comprehensive protection. It is certainly correct that for other technological developments, this rights framework has proven malleable and can be interpreted (e.g. through General Comments and recommendations by treaty bodies) to offer guidance to courts, legislators and regulators at the international, regional and national levels. Several UN human rights Special Rapporteur have called out the importance, and time sensitivity, of such action.[72] However it remains an open question among scholars whether a new norm or right to cognitive liberty would be necessary to frame and/or enable an updating of those rights.

Another important, albeit less discussed, component of this debate concerns political pragmatism. One symptom of today's deep polarization and reduced confidence in the multilateral system is a limited appetite for the expansion of existing rights, or the creation of new ones. Indeed, there is growing consensus that human rights are under unprecedented threat, marked by an expansion in authoritarian governance, narrowing of the rights protecting minority groups, and attacks on human rights defenders. There is legitimate concern, therefore, that a push for 'neurorights' might be met with — at best, a lukewarm response, and at worst — collective dismissal. This might problematize and/or delegitimize attempts to then invoke existing human rights as a bulwark against the risks posed, potentially resulting in an erosion in the overall level of protection enjoyed. In short, the invocation of a weakly (or even tacitly) supported 'neuroright' or convention could be worse than none at all. Against such possibilities, seeking an elaboration of existing rights (potentially through a framing mechanism of 'cognitive liberty') — many of which are recognized as part of international customary law[73] — is considered by many to be a safer pathway.

It is beyond the scope of this paper to discuss regulation in depth, nor the validity of 'neurorights' or 'cognitive liberty' as frameworks for this. Instead, it will present three observations that might frame, or should be considered, in those debates. These observations speak principally to the human rights community of practice, however they also have relevance to stakeholders in ethics, peacebuilding, biotechnology and neuroscience. Cutting across each of these messages is the need for a multi-sectorial and multi-dimensional approach. Neurotechnology is a dynamic field with many moving parts, vested interests and visions of success. These 'parts' need to be brought together, coordinated and cross-positions reconciled; most importantly, this effort needs to start sooner rather than later.

VIEWING THE POTENTIAL FOR HUMAN RIGHTS VIOLATIONS ALONGSIDE BROADER EXTERNALITIES

In examining the adequacy of the current rights architecture vis-a-vis the risks posed by neurotechnology, it is important to understand human rights violations as one component of a broader package of potentially negative outcomes. Some of these externalities will have direct human rights implications and require human rights responses. Examples include discrimination based on sexual orientation derived from 'brain hacking', the non-consensual collection of brain data, or cognitive manipulation. Other scenarios will not involve an infringement on human rights, but nonetheless warrant a response. One such concern is unemployment caused by neurotechnological applications replacing workers in a particular sector. Although this would impart negative consequences on the group, it would not constitute a human rights violation, meaning that a different type of solution would be necessary.

Unpacking these cause-and-effect relationships can be complex as externalities often bundle together or are mutually constituting. Consider for example a situation where enhanced reliance on neurotechnology reduces social interaction, causing an erosion in inter-group tolerance, which then spills over into racially-motivated violence. But distinction is important from a regulatory and solutions perspective; human rights provides a framework for responding to some of the risks that will be brought on by neurotechnology, but certainly not all of them. At the same time, the high level of inter-connection between externalities means that a comprehensive response is likely to be made up of several tools that speak to each other. Discussions on the role of human rights law, regulations aimed at protecting individuals from (non-rights violating) harms, and strategies to prevent broader problems such as diminutions in social cohesion or conflict spillovers, should thus take place in concert.

HUMAN RIGHTS AS PART OF THE REGULATORY SOLUTION, BUT NOT A SOLUTION IN AND OF ITSELF

Irrespective of whether 'neurorights' are recognized, or an elaboration of the existing framework deemed sufficient, regulating the development and sale of neurotechnology effectively and consistently will continue to be challenging. A first issue is untangling how neurotechnology interacts with other digital technologies — particularly artificial intelligence. Indeed, a malign human rights outcome will not be due to the neurotechnology itself but a technology underpinning it. As discussed, companies now use EEG to glean insight into what products, branding or features appeal to a specific consumer group. As long as this is done consensually and does not target vulnerable groups, human rights are unlikely to be impacted. Only when this technology is paired with platform-enabled algorithms designed to addict, manipulate or compel, do rights become vulnerable to encroachment, begging important questions around whether it is the neurotechnology or the AI dimension that needs to be delimited.

UNPACKING THE FULL TYPOLOGY OF EXTERNALITIES STEMMING FROM NEUROTECHNOLOGY APPLICATIONS

Examples of negative externalities not involving human rights violations	Examples of negative externalities that might spill over to include human rights violations
▪ One consequence of automation, mechanization and artificial intelligence has been job losses skewed towards educationally, financially and other disadvantaged groups, increasing poverty, and exacerbating inequality and class divides. Neurotechnology is likely to cause similar results as companies take advantage of innovations such as mind-to-text typing, mind-based simultaneous language translation, and neural (as opposed to in-person) meetings. ▪ Commercial and recreational neurotech applications, such as neuro-gaming, neuro-shopping, neuro-meeting/socializing and BMI-regulated administration of medication may reduce social contact, communication and connectedness, creating potential impacts for mental health, social cohesion, and relatability. ▪ Unequal access to cognition maximization has the potential to widen power asymmetries and inequality (within and between countries), with spillovers for broader goals such as poverty reduction and positive ends such as multilateral cooperation. ▪ Self-determination, agency74 and self-narrative are critical components of the human condition and closely connected to important non-cognitive traits such as grit, integrity, empathy, conscientiousness and perseverance. The ability to interfere with cognitive traits and the 'demystification' resulting from neural mapping may alter how individuals view their existence, with spillovers for life satisfaction, mental health and social cohesion.	▪ Brain mapping to identify proficiencies (or non-proficiencies) could be used to facilitate the streaming of individuals into education and/or specialist vocations. This could deepen social segregation along neuro-cognitive lines, narrow the scope for diversity in inter-personal interaction, and limit self-determination (an individual's capacity to direct their life's trajectory, and the autonomy to engage in a satisfying/rewarding but not productive vocation). ▪ Currently, what individuals believe and think, and how they express and act on those thoughts and beliefs, is a matter of self-regulation, choice and agency. This 'barrier' between belief and action is regulated by a combination of social norms and laws. For example, an individual might harbor racist beliefs, but not express or act upon them because it would be deemed socially unacceptable and/or illegal. This barrier is key to containing violence, prompting social cohesion and managing discrimination. But it is tenuous. The rise of private internet chat groups, for example, gave persons with racist and homophobic views space to express them, a community of likemindeds and sense of validation. This spilled over in both legal (group polarization) and illegal (violence and discrimination) ways. Insofar as neurotechnology similarly interferes with this barrier – by eliminating thought privacy and thus exposing individual beliefs –similar impacts may accrue.

Another part of this problematic is the private sector dimension. As the Business and Human Rights literature sets out, despite a responsibility for companies to respect and uphold human rights, there is no enforcement or accountability framework at the international level. At the same time, domestic law and policy will generally vary in its robustness and application, and can be evaded by creative constructs such as shell companies. These realities have implications for where neurotechnology is likely to take place and for what purposes. For most private sector developers, operating under a strict regulatory framework will be advantageous — for example where this offers a pathway to commercial roll out or to access certain export markets. But this will not be the case for all. With the technical capacity and resources to develop neurotechnology independently, some companies will take advantage of digitalized technologies' ease of transfer and the integrated nature of globalized economy to strategically locate in whichever regulatory environment offers the fewest restrictions. This particularly concerns entities pursuing malign ends or wishing to sell their products on unregulated markets.

The other dimension of the regulatory challenge is the incentives held by States to 'lead' on neurotechnology. Indeed the twin challenges identified above — the scope to develop neurotechnology for socially disruptive or nefarious ends and the difficulty in regulating this potential — have become somewhat self-reinforcing. With glaring similarities to the nuclear arms race, governments increasingly see the best means of protecting their citizens from weaponized neurotechnology to be developing it themselves.

Bringing these elements together, domestic law and regulation is currently the most effective framework to protect individuals from the risks posed by neurotechnology. Human rights will be an important tool through which to craft such rules. However, the incentives to develop neurotechnology — both for legitimate and non-legitimate means — are such that the uptake of a common framework grounded in minimum standards is unlikely. Strong national legislation will thus need to be complemented by import laws and other trade controls, laws around enabling technology such as AI, corporate self-regulation and arguably some form of supra-national oversight mechanism that can monitor industry, non-state groups, and states themselves.

THE CHALLENGE OF SETTING 'RED LINES' AROUND NEUROTECHNOLOGY

Finally, while the possible misuses of neurotechnology speak to a logic of strict regulation, where such lines should be drawn will likely be contested and very much determined by dynamic societal norms. It must be recognized that neurotechnology — like all innovation — will be subject to forces of progressive normalization (whereby concepts deemed radical, incoherent or dangerous become normalized through use, with familiarity and over time). Antidepressants, predictive text and cochlear hearing aids, are all examples of innovations that were initially considered unethical or an inappropriate interference in the human condition.

A more complicated challenge will be striking a suitable balance that enables innovation and protects rights. As set out below, strong arguments can be levelled in support of neurotechnology, including neuro-enhancement to tackle global challenges like climate change or improve public safety, and 'brain hacking' to prevent the perpetration of terrorism or atrocity crimes. Indeed, the right to enjoy the benefits of scientific advancement is set out in international human rights law.[75] Applying this same technology to a different context, however, will be highly contested, from both a human rights and ethical perspective. Examples include employers mandating cognitive enhancement, or law enforcement using brain data to reveal sexual orientation in jurisdictions where LGBTQI+ rights are not recognized.

Farahany adds a further nuance to this debate. She points out that many of the neurotech applications that attract rights-grounded criticisms are extensions of behavioral norms that underpin the most typical human relationships and are observable from early childhood. Examples include attempting to interpret someone's emotions to regulate one's own behavior ('mindreading') or convincing someone to adopt your course of reasoning by appealing to their sensitivities ('cognitive manipulation'). The point is that protecting individual rights is not as easy as prohibiting what — in the extreme — may be seen as a malign application of neurotechnology. A line needs to be drawn between what is deemed acceptable and unacceptable interference in human decision-making, thoughts and emotions and international human rights law does not necessarily provide this guidance. Ethicists, psychologists/psychiatrists, behavioral scientists, neuroscientists etc. will prove be critical voices in these conversations. In short, debates on regulation will need to acknowledge that while human rights are universal, the backdrop against which neurotech regulation is being crafted is dynamic, malleable and evolving according to subjective and contested criteria. Most importantly, because reaching agreement on how to maximize positive innovation and minimize negative externalities is likely to be so complex, this process needs to be prioritized and accelerated.

TABLE 4. A THOUGHT EXERCISE DRAWING 'RED LINES' IN REGULATING NEUROTECHNOLOGY

Cognitive enhancement	Brain mapping and decoding
Should neuro-enhancement technology be permitted to fast-track solutions for global challenges such as climate change, diseases such as cancer or threats such as a future pandemic?	Should brain decoding technology be used to identify and stop individuals harboring suicidal, homicidal, pedophiliac, terrorist or other criminal intent/ideation?
Should human enhancement be available to professionals in service professions such as healthcare, teaching and justice administration? Should human enhancement be available to CEOs, political leaders or military commanders whose decisions materially impact large populations?	Should the use of brain decoding technology extend to racists, or those holding extremist political or religious views? Should brain decoding be permitted to identify individual acumen or talent in the same way as career counselling or profiling?
Should neuroenhancement or cognition maximization be accessible by any individual who voluntary seeks it?	Should voluntary brain decoding be seen as a human right to access personal information, or a means of accessing personal data akin to a blood test?
Should employers be permitted to mandate enhancement as a condition of employment if this is freely contracted?	

CONCLUSION

Each wave of advancement in digital technology has created opportunities for the promotion, expansion and application of human rights, as well as their encroachment and delimiting. What is different about this present wave is the advent of AI and machine learning, and the exponential rate of innovation this has enabled, including in neurotechnology. AI and machine learning are also responsible for the commercialization of neurotechnology, and thus the shifting of its development, production and retailing away from the (highly regulated) medical sector and into a market with essentially no regulation. The upshot is a very real risk that neurotechnology will grow and disperse without taking into account human rights, or other negative externalities in areas such as social cohesion and conflict. As governments start grapple with this, several obstacles can be identified. First, their focus is not only neurotechnology; digital military technology, cyber technology, quantum computing etc. all pose extant threats and compete for attention in the policy arena. Another complication is the vested interests — state, military and private sector — opposed to a stringent regulatory framework. Rightly or wrongly, human rights will inevitably face off with other government imperatives such as nurturing innovation, expanding market opportunities and mitigating security threats. To assist in resolving these tensions, this paper has set out the evolution of the corporate neurotechnology sector, discussed four rapidly emerging neurotechnologies, and offered some ideas on the role that human rights might play in emerging regulatory debates. Important next steps will include a detailed mapping of where neurotechnology might impact human rights, or create changes in societal functioning that spill over into human rights violations. This process must be interdisciplinary, bringing in technologists, neuroscientists, ethicists, regulators, as well as human rights experts. Such inclusion will prove crucial in the crafting of regulation that supports innovation while respecting human rights, deterring misuse, and ensuring accountability.

END NOTES

1 Sincere thanks are extended to Professor Nita Farahany for comments made on this paper

2 UNESCO (2023) 'The Risks and Challenges of Neurotechnologies for Human Rights', p. 3.

3 There has been a 700 percent increase of investment in neurotech companies from 2014 to 2021, bringing the overall investment to USD 33.2 billion; see UNESCO www.unesco.org/en/ethics-neurotech.

4 UNESCO (2023) 'The Risks and Challenges of Neurotechnologies for Human Rights' (2023), p. 3. See also, Müller, O. and Rotter, S. (2017) 'Neurotechnology: Current Developments and Ethical Issues', Frontier in Systems Neuroscience, 11:93, pp.1-2; Lynch, Z., (2004) 'Neurotechnology and Society (2010–2060)', Annals of the New York Academy of Sciences, 1013:1, pp.229-233; OECD Recommendation of the Council on Responsible Innovation in Neurotechnology OECD/LEGAL/0457 (2022).

5 In the U.S., the private sector is now outpacing federal funding in developing new neurotechnology Yuste, R., Genser, J. & Herrmann, S. 'It's Time for Neurorights: New Human Rights for the Age of Neurotechnology' Horizons Vol.18 p.157.

6 Deep brain stimulation uses implanted electrodes that give off electrical impulses to regularise abnormal neural activity including in individuals suffering from tremors, epilepsy and Parkinson's disease. The same technology can be applied to electrodes implanted in the spinal cord to enable movement in persons suffering from types of paralysis.

7 Transcranial Magnetic Stimulation is a non-invasive procedure used to treat psychiatric and neurological disorders such as depression and Post Traumatic Stress Disorder.

8 Transcranial direct current stimulation modulates behavioral and cognitive processes via electrical currents. The main medical use is to assist individuals with Attention Deficit Disorder, but it could theoretically be used in healthy patients to modify behavior, accelerate learning and/or boost task performance.

9 Focused ultrasound allows for the manipulation of brain activity in a highly selective manner by stimulating or inhibiting specific neural circuits, for example to treat tremors.

10 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp 41, 71-72, 121-122, 131-132, 142.

11 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 141-142, 203.

12 The BMI has a long development history. In 1964, Spanish neurophysiologist José Manuel Rodríguez Delgado, brought a bull to a standstill using radio-controlled electrodes embedded in the animal's brain. In the 1970s, the University of California Los Angeles professor Jacques Vidal coined the term brain-computer interface and demonstrated that people could mentally guide a cursor through a simple virtual maze. The next breakthrough came in 2003, when scholars at Duke University published research outlining how monkeys implanted with neural interfaces could operate mind-controlled robotic prostheses; see Carmena J.M., Lebedev M.A., Crist R.E., et al (2003) 'Learning to control a brain-machine interface for reaching and grasping by primates' PLoS Biol. 1(2):E42. In 2004, neural implants were first put to therapeutic use, allowing a paralyzed individual to perform basic functions such as operating a television remote control and playing computer games, again using only their mind. In 2015, researchers at the University of Houston succeeded in an amputee controlling a prosthetic hand with an EEG headset (i.e. not an invasive brain implant); Agashe, H., Paek, A., Zhang, Y. et al (2015) 'Global cortical activity predicts shape of hand during grasping' Front. Neurosci Vol.15.

13 Approved for therapeutic use in the 1980s, the cochlear implant is an external microphone that transmits radio signals to electrodes implanted in the auditory nerve.

14 Artificial retinas pick up sensory (visual) stimuli from the environment via a sensor and transmit these to the nerve responsible for sending them to the brain.

15 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp65-87.

16 Garden, H., Winickhoff, D.E., Frahm, N.M. et al (2019) "Responsible Innovation in Neurotechnology Enterprises' Working Paper OECD, p.10.

17 Globally, one in eight individuals live with a mental or neurological disorder; www.unesco.org/en/ethics-neurotech. See further, Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp 131-132.

18 Such costs are estimated to reach USD6 trillion by 2030; Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp 10-14, 44.

19 Tau, G., Peterson, B. (2010) 'Normal Development of Brain Circuits' Neuropsychopharmacol 35, 147–168 (2010). https://doi.org/10.1038/npp.2009.115.

20 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 36-38.

21 Goering, S., Klein, E., Specter Sullivan, L. et al (2021) 'Recommendations for Responsible Development and Application of Neurotechnologies' Neuroethics, p.8.

22 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 148-153.

23 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 160-162.

24 As noted by Kenneth Wenger, consumers "don't stand a chance against the relentless power of an optimization algorithm". Wenger, K. (2023) Is the Algorithm Plotting Against Us?: A Layperson's Guide to the Concepts, Math, and Pitfalls of AI Working Fires Foundation, 208-211. A comparison might be made to the controversial industry practice of 'bliss point' science in food production. Here, researchers work to identify the precise combination of ingredients (principally sugar) needed to make foods optimally desirable, and use this as the basis of producing, for example, children's breakfast cereals. When the practice was unmasked in the early 2000s, swaths of governments sought to introduce limitations, including 'sugar taxes'.

25 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 156.

26 See further, Garden, H., Winickhoff, D.E., Frahm, N.M. et al (2019) "Responsible Innovation in Neurotechnology Enterprises' Working Paper OECD, p.18.

27 Yuste, R., Goering, S. et al 'Four ethical priorities for neurotechnologies and AI' (2017) Nature 551, p.159.

28 Helliker, K. (2019) 'Unbroken: Mark Pollock', Brunswick Review; Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 84, 92-94.

29 Mackellar, G (2020) 'Mind Over Matter' Macquarie Matters; Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, p. ix.

30 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 68.

31 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 106, 115-123.

32 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 21, 198-201.

33 In 1998, Professor Kevin Warwick became the world's first cyborg after being implanted with a radio frequency identification device allowing him to open doors, pay for drinks and unlock a computer, using his mind. Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 99, 105-112.

34 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 96-98.

35 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, p. 62.

36 DARPA's soldier cognition enhancement program began in 2001; Clark, V.P., Coffman, B.A.,

Mayer, A.R. et al (2012) 'TDCS guided using fMRI significantly accelerates learning to identify concealed objects' Neuroimage 59:1 pp.117-128. TDCS headsets are also used by elite athletes; see e.g. Edwards, D., Cortes, M., Wortman-Jutt, S. et(2017) 'Transcranial Direct Current Stimulation and Sports Performance' Front. Hum. Neuroscience 10 :2017. Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp, 19-21, 57-63, Anguera, J.A. et al (2013) 'Video Game Training Enhances Cognitive Control in Older Adults' Nature 501(7465):97-101.

37 The use of such medicines in healthy individuals to boost attention, cognition and executive function is increasing and the practice is banned at a number of universities; Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 116. The US Defense Advanced Research Projects Agency (DARPA) has developed a synthetic ingestible that simulates fasting to enhance stamina and physical performance in the recipient; Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp.3-9.

38 Forlini C. & Hall W. (2016) 'The is and ought of the Ethics of Neuroenhancement: Mind the Gap', Front Psychology 8;6:1998. doi: 10.3389/fpsyg.2015.01998; Fukuyama F. (2002) Our Posthuman Future New York, NY: Picador; Sandel M. J. (2004) 'The case against perfection: what's wrong with designer children, bionic athletes, and genetic engineering', Atl. Mon. 292 50–54; Kass L. (2003) Ageless Bodies, Happy Souls New York, NY: The New Atlantis Spring, 9–28.

39 Buchanan A. (2010) Better Than Human: The Promise and Perils of Enhancing Ourselves. Oxford: Oxford University Press; Caplan A. L. (2003) 'Is better best? A noted ethicist argues in favor of brain enhancement' Sci. Am. 289 104–105; Savulescu J. (2006) 'Justice, fairness, and enhancement' Ann. N. Y. Acad. Sci. 1093 321–338.

40 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, p.7.

41 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 118-126.

42 Goering, S., Klein, E., Specter Sullivan, L. et al (2021) 'Recommendations for Responsible Development and Application of Neurotechnologies' Neuroethics p.13.

43 Goering, S., Klein, E., Specter Sullivan, L. et al (2021) 'Recommendations for Responsible Development and Application of Neurotechnologies' Neuroethics p.13.

44 Neurofeedback involves using a machine to monitor brainwaves, and then translate this data onto an audio or video display. Techniques are then applied to teach people how to regulate their brain function for improve focus, manage pain management, treat depression etc. The brain training device /game market is currently worth USD8 billion and is estimated to grow to USD57 billion by 2025; Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp.48-51, 111-114.

45 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, p. 43.

46 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 40-46.

47 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 4-5, 29-30, 67.

48 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 41-42.

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53 Mitchell, T.M., Shinkareva, S.V., Carlson, A. et al (2008) 'Predicting Human Brain Activity Associated with the Meanings of Nouns' Science, 320:5880 pp. 1191-1195 DOI: 10.1126/science.1152876

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55 Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. Le29-33, 203-204.

56 In fact, this advancement was pioneered in 2017 in Duke University with funding from DARPA. Similarly, the company Kernel is working to develop a neural interface that can read and write from the brain; Le, T. (2020) The Neurogeneration: The New Era in Brain Enhancement That Is Revolutionizing the Way We Think, Work, and Heal. Benbella Books, pp. 92-94, 125.

57 Paul, K 'Fears over DNA privacy as 23andMe plans to go public in deal with Richard Branson' The Guardian, 9 February 2021 theguardian.com/technology/2021/feb/09/23andme-dna-privacy-richard-branson-genetics. It is noteworthy that a review of the privacy policies attached to currently available neurotech devices revealed that a vast majority state neurodata is collected, filtered through a proprietary algorithm and stored for use, Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 19, 30.

58 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, 17-18.

59 Goering, S., Klein, E., Specter Sullivan, L. et al (2021) 'Recommendations for Responsible Development and Application of Neurotechnologies' Neuroethics p.9.

60 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, p.18.

61 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 32, 78-83.

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68 At the 26th (Ordinary) Session of the International Bioethics Committee in July 2019, a Working Group was established to develop an initial reflection on neurotechnology. The report of the group was released in 2021. Report of the international bioethics committee of UNESCO (IBC) on the ethical issues of neurotechnology, Paris, 15 December 2021.

69 On 21 June 2022, the Interamerican Commission held a public audience on "Human Rights and Neurotechnologies (https://www.oas.org/es/cidh/sesiones/?S=184). See also, Declaration of the Interamerican Juridical Committee on Neuroscience, Neurotechnologies and Human Rights: New Legal Challenges for the Americas, CJI/DEC. 01 (XCIX-O/21). On 9 November 2021, the Council of Europe and the OECD co-organized a round table under the title: Neurotechnologies and Human Rights Framework: Do We Need New Rights? https://www.coe.int/en/web/bioethics/round-table-on-the-human-rights-issues-raised-by-the-applications-of-neurotechnologies. See also, Ienca, M. (2021a), 'Common human rights challenges raised by different applications of neurotechnologies in the biomedical field '. Report commissioned by the Committee on Bioethics, Council of Europe.

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71 Farahany, N. (2023) The Battle for Your Brain: Defending the Right to Think Freely in the Age of Neurotechnology, St. Martin's Press, pp. 211-214.

72 Indeed in 2021, UN Special Rapporteur on Freedom of Religion or Belief called out how the notion of 'thought' as a right has been narrowly interpreted and inadequately interrogated; UN General Assembly 'Promotion and protection of human rights: human rights questions, including alternative approaches for improving the effective enjoyment of human rights and fundamental freedoms' A/76/330 (2021). The Special Rapporteur on the Promotion and Protection of the Right to Freedom of Opinion and Expression and Special Rapporteur on Right to Privacy have likewise argued for an expansion in guidance. See further, Ligthart, S. et al (2022) 'Rethinking the Right to Freedom of Thought: A multidisciplinary Analysis' Hum Rights Law Rev 22 pp.1-14.

73 Examples include freedom of opinion and expression (UDHR art 19), freedom of thought, conscious and religion (article 19) and the right to privacy (UDHR article 12).

74 Agency here refers to an individual's ability to consciously make and communicate a decision or choice.

75 Art 27 Universal Declaration of Human Rights (1948).

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NEUROTECHNOLOGY AND HUMAN RIGHTS

Our research project – conducted in partnership with the Geneva University Neurocentre and the United Nations Human Rights Council Advisory Committee – addresses the human rights implications stemming from the development of neurotechnology for commercial, non-therapeutic ends.

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