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# GESDA Impact Story

Neurotechnologies

Geneva, July 2022

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# Executive Summary

**What is neuroscience ?**
**Neuroscience** is the study of the nervous system, the basis for the understanding of learning, memory, behavior, perception, movement and consciousness. It is a multidisciplinary science that combines medicine, physiology, anatomy, biology, computer science and mathematical modelling, as well as the ethics of related advances.

**What is neurotechnology ?**
Devices and procedures used to access, monitor, investigate, assess, manipulate, and/or emulate the structure and function of the neural systems of natural persons. (OECD 2019)

**Note:** In this article, we only consider neurotechnology at the interface with the central nervous system (brain and spinal cord). Some neurotechnology also interfaces with the peripheral nervous system which includes all nerves in the body.

Recent technological advances in electronic miniaturization and brain signal detection, and the use of artificial intelligence (AI) for data analysis, pave the way to better understand the brain and treat neurological and mental health disorders. These have given neuroscience and neurotechnology **a great boost**, generating huge financial investments from the public and private sectors.

Neurotechnologies can be **invasive**, when penetrating the skull, or **non-invasive**, when used at its surface. They are being applied for clinical purposes. With around 1 billion people suffering from relevant disorders in the world, they are proving to be of great medical value. At least 200,000 patients worldwide live with a neural implant of some kind, mainly deep brain stimulation electrodes to limit the effects of Parkinson's disease. Neurotechnologies also have applications beyond the medical field such as in neuromarketing, gaming and entertainment, as well as in the military domain.

Although neurotechnologies now allow brain data to be recorded with great precision, researchers are still working to fully **understand** these signals. Most neuroscience studies show correlations between mental states or behaviors and brain activity, but it is more difficult to show causal links. Large amounts of data from various levels (from neuron to behavior, through the activity of brain areas) still need to be acquired and integrated before explaining how neuronal activity and mental states are specifically associated. Some neuroscientists consider that, thanks to advances in computing power and AI, it is only a matter of time for this to be possible.

Neurotechnologies are developed in **public** or **private research laboratories**, first with clinical and therapeutic applications, and sometimes later with applications for the general population. Private actors, such as start-up companies, have emerged, bringing the technologies to patients more quickly or directly to consumers. Patients and consumers are also getting involved in developing these technologies through advocacy and engagement initiatives.

Neurotechnologies generally have a positive impact but their evolution can raise ethical, societal, economic, and legal concerns, mainly when applied outside of the research and clinical setting. Positive and negative **impacts** can be on multiple fronts: on the personal level on **privacy**, **identity**, **sense of agency**, **cognitive liberty**, **equity**; on more technical issues such as **standardization** of methods for inter-operability for criminal prosecution purposes" or in the judicial domain, **commercialization** and **regulations**, **military** uses; and, on the societal level in the utilization in the judicial domain.

Such challenges point towards the need for responsible approaches and frameworks for action on all fronts, starting on the research and innovation level, taking into account ethical, cultural, sociological and philosophical considerations, and ending with flexible but forward-looking governance and regulation schemes on the multilateral international level.

## 1. Three ways to interact with the brain: read, modulate, or both

### 1. 1. Reading brain activity

Some neurotechnologies can record brain activity, giving researchers insights into how thoughts, feelings and mental states are encoded in the brain, and enabling them to infer a person's mental state and acquire health information.

#### CASE 1 (Invasive, clinical): Help disabled people communicate and move again

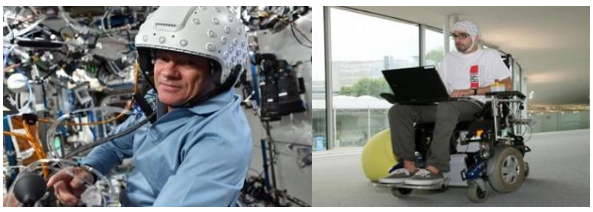
Paralyzed and locked-in patients can interact with the outside world through implanted chips connected to brain-computer interfaces (BCIs). These chips, made of tens of tiny electrodes (image), detect the brain activity associated with the thinking of a movement, and translate them into commands for a cursor on a computer screen or a robotic device such as a motorized wheelchair or prosthetic arm (image). While these systems are at the clinical research stage and as yet there is no such implantable device commercially available, rapid advances could make brain implants the next computer mouse. Early in May 2022, the firm Synchron enrolled the first patients in its US clinical trial to test what could be the first commercial BCI, which takes the form of a stent (a tiny tube) rather than a chip. Further developments will enable BCIs to control increasingly complex devices, such as exoskeletons or virtual avatars, which could allow more diverse interactions with the world.

Importantly, researchers still do not know how to interpret the brain activity linked to complex or conceptual thinking based on BCI signals. But the field is moving fast: in 2021, researchers generated rudimentary speech in real-time from the brain activity of a patient as he imagined spoken words. Ethical questions regarding the extent to which such proxy signals could be used in high consequence communication, such as decisions about continuing with life, are being debated today.

This technology could at some point be applied to healthy people, to type a text or send emails just with thoughts, or to play a video games. But this would involve implanting the devices into able-bodied individuals, so would first need clearance from regulators. An immediate and realistic next step would be to facilitate movement in paralyzed patients by using the same signals to directly stimulate the limb (a first clinical trial took place in the US) or spinal cord, which controls the muscles through the nerves.

Among many companies developing ever smaller, safer and easier-to-insert systems, Neuralink is the most visible. While working to help people with paraplegia walk again, Neuralink also claims that its technology will help to "create a whole brain interface capable of more closely connecting biological and artificial intelligence", and even to "save memories" stored in the brain onto an external hardware so that the owner – or anyone – can revisit them like photo albums. However, how the brain codes complex thoughts and actions is still unknown, or how it stores and retrieves memories. So experts say that this neurotechnology is still far off.

#### CASE 2 (Non-invasive; clinical, consumers): Check someone's brain states



Electroencephalography (EEG) records the brain's electrical activity via removable sensors applied to the scalp surface. Developed in the 1920s, EEG hugely increased the understanding of the brain. It is now widely used in research as well as to diagnose disorders like epilepsy, stroke, sleep disorders, coma or encephalopathies. It has even been tested in space (most recently early April 2022 – image, left) to measure changes in brain activity caused by microgravity.

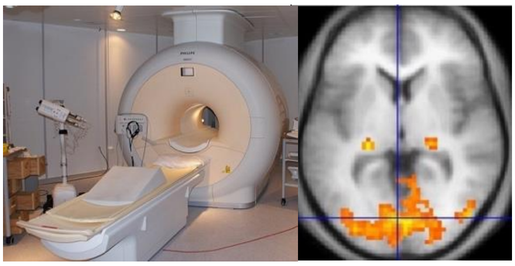
This technique has relatively poor spatial resolution: it is difficult to know exactly where the recorded signal comes from, although detection hardware and software and analysis techniques are improving this. It is also limited by its sensitivity to movement that can interfere with the reliable recording of a signal. But EEG is sensitive enough to detect simple intentions, such as the intent to move a body part. This signal can then be used to drive external devices, like a wheelchair (image, right – see also Case 1).

Although decoding complex thoughts is still an anticipatory goal, if not out of reach, EEG can be used to gauge simpler brain states. In Australia, for example, EEG caps that track fatigue in truck drivers have been used on mine sites, and in China, commercial EEG headsets were tested in 2019 on pupils to inform teachers about their concentration and focus; the effectiveness of such devices is debatable,: expert say that EEG "must be combined with other measurements" to "diagnose attention disorders". And the signal recorded with consumer-level systems may not be sufficient to precisely evaluate one's attentional level.

EEG is now used outside research and medicine. An artist has created a unique experience in which the viewer, wearing an EEG headset, could change the narrative and sound of a movie, providing many possible narrative combinations. EEG is also being used in gaming, with a proof of concept of a football match, where the ball is moved by the players' thoughts. According to scientists though, its use in gaming is still not ready for the general public, for technical reasons.

Recently, much effort has been made to develop simple wearable EEG headsets, including devices with discrete tattoo-like electrodes. This raises the possibility of EEG recordings to study real-world brain dynamics in response to a range of external stimuli over longer periods. New areas of research are emerging, such as *team*-EEG or EEG-*hyperscanning*, where the brain activity of groups of people are monitored simultaneously. Overall, the wearable EEG device market is growing, but it is important to note that there are major differences in terms of validation between the use of EEG in brain research compared to its applications in direct-to-consumer tools, for which efficacy is questionable.

## CASE 3 (Non-invasive, clinical): Decipher mental images and quantify thoughts



Functional magnetic resonance imaging (fMRI) measures brain activity indirectly by monitoring changes in cerebral blood flow (images). This external method has been in use for three decades to study the healthy and diseased or injured brain. Recently, scientists used fMRI combined with AI to decipher and reconstruct images from a movie a participant was watching, just based on the acquired signal on his brain. Researchers in Japan have used fMRI to reveal, with 60% accuracy, the images people dreamt of as they fell asleep, as some media reported. In 2019, the same team also claimed to reconstruct images from recalled memories.

Various groups are also using fMRI to try to communicate with patients in varying degrees of apparently unconscious states due to brain injury: researchers and clinicians need to train the patients to create, in their brain, patterns of activity corresponding to a distinctive 'yes' or 'no'; those same patterns can be recorded and then looked for when the patient answers new questions. This promises to better diagnose consciousness disorders, which affect up to 322,000 persons in the US. Another group has succeeded in decoding the brain activity associated with chronic pain, which is difficult to measure objectively as doctors have to rely on patient's self-reports; such findings are close to being translated into clinical use. Also, for a few years, a controversial line of research suggested that fMRI could be used to distinguish between true memories, false memories, and lies (a last case in which accuracy has shown to be very poor, for now). According to a book review in *Nature*, however, "these methods don't yet enable researchers to decode the 'language of thought', which is what mind-reading connotes for many".

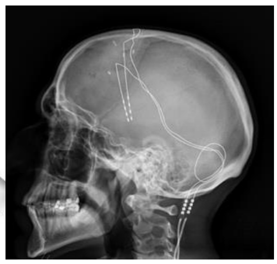
A historical drawback of fMRI was that it needed a large machine and could only be used in a lab or hospital setting. Since a few years, this has changed, as portable fMRI apparatuses are being developed, showing first results to image stroke.  Kernel, a US company, claims that it has developed a wearable helmet that performs similar measurements with a slower, light-based technique called time-domain functional near-infrared spectroscopy (TD-fNIRS). A consumer model of the helmet (image) has been announced for 2024, and Kernel's founder wants the device in every US home in the next decade. Its purpose remains unclear, but, according to one neurotech expert, "the use cases will come – once the devices are built [...],  it might be possible to quantify abstract and ill-defined concepts, like focus, cognitive load, aging, mental health, pain and a slew of others."

## 1.2. Modulating brain activity

Some neurotechnologies modify brain's activity transiently or permanently, by interfering with neuronal functioning. These methods alter, enhance or inhibit specific brain functions, and are used for both research and treatment.

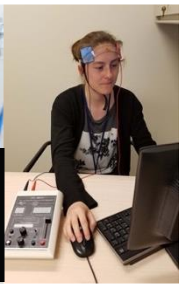
### CASE 4 (Invasive, clinical): Cure (and enhancement) with electric pulses

Deep brain stimulation (DBS) is a highly invasive experimental procedure involving surgical implantation of a "brain pacemaker" consisting of wire electrodes. Since 1997, more than 200,000 Parkinson's Disease patients have received DBS to alleviate their tremors with electric pulses. The technique is now being tested as a treatment for obsessive-compulsive disorder, epilepsy, post-traumatic stress disorder and depression. Physicians are also using DBS to treat obesity, alcoholism and drug addiction. In 2010, a Stanford University team used the technique to prevent mice from overeating by sending electrical signals to their brain to restore control. "The lack of impulse control that may underlie addictive behavior isn't a choice, but results from a malfunction of the brain", he told the *NY Times*. Since then, DBS has been tested to treat food craving and obesity in humans. It is also being tested to treat Alzheimer's Disease, with the intent to slow memory decline or enhance memory performance. This raises the question of how far it would be possible to modulate human memory more generally.

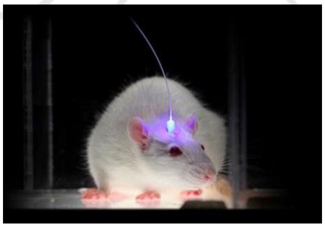
### CASE 5 (Non-invasive, clinical): Treat depression, enhance cognition

Two external stimulation methods are being used to treat drug-resistant depression: 1. Transcranial magnetic stimulation (TMS – image, left), which uses a magnetic coil to alter the brain's electrical activity, and 2. Transcranial direct-current stimulation (tDCS – image, right), which uses constant, low intensity direct electrical currents delivered via electrodes placed on the scalp. A small meta-analysis shows that TMS appears to improve cognitive functions such as verbal learning and memory in patients with mild cognitive impairment. Notably, these improvements were obtained after single sessions lasting a few hours, but it is still unclear if the effects might last longer. Even so, a self-described 'wellness spa for the brain' now offers TMS to healthy people, claiming that it 'restores the brain to its optimal factory settings'.



Other research suggests that tDCS can also enhance episodic memory, vigilance, attention, decision-making and reaction times. The first consumer tDCS wearable, a headset for gamers, appeared on the market in 2013, and today, the Do-It-Yourself brain stimulation community is growing quickly. According to *Scientific American:* "Most consumer tDCS devices are [...] for leisure and cognitive enhancement. None [...] have officially undergone the rigorous testing [needed] for approval by the US Food and Drug Administration (FDA), and the purchaser has only the manufacturer's claim that it works for its intended use. [...]. Despite uncertainty over efficacy claims, interest in tDCS as a tool for optimizing mental function persists. And it looks like tDCS is only the beginning", or the "tip of the iceberg" according to a quoted expert."

### CASE 6 (Invasive, labs): Driving the brain genes with light

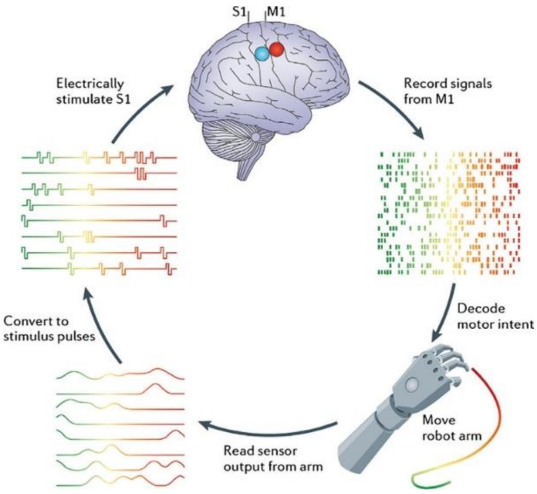


Optogenetics is a technique that can manipulate brain activity with a very high precision, by inserting genes into neurons that render the cells sensitive to light. This enables researchers to switch the cells on or off just by using pulses of laser light target on those sensitive cells. In this way, neuroscientists at Columbia University controlled the visual behavior of a mouse by activating a few neurons in its visual cortex: "We were able to implant into these mice perceptions of things that they hadn't seen," the author commented in the *NY Times*. "We manipulated the mouse like a puppet." And in 2021, scientists drove mice to bond by zapping their brains with light, using the same technique. Another type of gene makes host neurons emit detectable fluorescence when activated, enabling researchers to see which cells fire while an animal is performing any particular task. The possibilities of optogenetics seem endless. In 2021, a clinical case study described partial recovery of visual function in a blind patient after optogenetic therapy: without seeing colors, he could clearly identify objects of the lab. A similar technology, called sonogenetics, involves inserting genes that render neurons sensitive to ultrasound. Both methods, while being very accurate and efficient to manipulate the brain, remain very invasive, requiring genetic engineering. In optogenetics, light is delivered via an optical fiber implanted into the brain; recently, researchers developed a non-invasive way of delivering light from distances of up to 1 meter.

«The ability to optically control neural activity opens up possibilities for the restoration of normal function following neurological disorders. The temporal precision, spatial resolution, and neuronal specificity that optogenetics offers is unequalled by other available methods, so will it be suitable for not only restoring but also extending brain function? », asked two experts in a review article on prospects for optogenetic augmentation of brain function.

## 1.3. Closing the loop between the machine and the brain

### CASE 7: Closed-loop systems




Some neurotechnologies allow for simultaneous recording and modulation of brain activity. Such techniques often combine different methods for recording and modulating with algorithms to interpret the activity. The decision on how to modulate the brain's activity can be made manually by the user or clinicians, or automatically by the system itself, according to programmed rules.

Many research groups are working on such "closed-loop" systems, which would "adapt" to each patient, allowing a more efficient interaction with the machine. These systems could improve the use of invasive devices, as shown in 2019 for deep brain stimulation (DBS) in Parkinson's disease for example. For instance, the system could detect the onset of abnormal brain activity and stimulate the brain only when needed, and machine learning can improve the detection of precursory signals. This may eventually lead to improved, personalized treatments that have fewer potential side effects.

A project funded by the US military has also proposed closed-loop systems using algorithms to treat mood disorders: "Brain implants that deliver electrical pulses tuned to a person's feelings and behavior are being tested in people for the first time". This implies to constantly monitor of neural activity to detect changes in mood and directly alter it using electrical pulses. One challenge with this is "the possibility of overcorrecting emotions to create extreme happiness that overwhelms all other feelings", says an expert. The algorithms used in closed-loop systems can also "tell the researchers about the person's mood, beyond what may be visible from behavior or facial expressions."

Closed-loop systems can also be used to control machines and get feedback from them. State-of-the-art neuroprosthetic arms can send sensory information to the patient's brain, to indicate, for example, whether a surface is hot or cold. Restoring touch and proprioceptive information in this way will not only make the prosthesis feel more realistic for its user, but will also make it easier to control. Recent research shows that it is even possible to enhance the sense of agency for BCI actions: the patient is feeling that it is only he/her – or his/her brain – who really have voluntary control over the machine. In a recent study, scientists at EPF Lausanne managed to improve a tetraplegic patient's feeling of agency over a prosthetic arm by altering the visual and tactile feedback he received from his arm movements. This improved the functioning of the whole BCI system. Patients can therefore control the actions of a machine, feel their environment through it, and have the feeling of fully controlling it as if it were actually a part of their body, obeying directly to their brain – and not to a program decoding its signals. Such prostheses could eventually be used to enhance physical performance in healthy people.

## *2. Personal impacts*

### 1.1 On (brain data) privacy

Brain data, whether they detail the physiological structure of the organ or its functioning through the activity of neurons, are extremely personal. Because they may provide information that are generated unconsciously about physiological reactions, decision-making, emotions, attention span, and sexual orientation (see Case 2 & 3), they can be highly sensitive.

The question of who has **access** to such data raises ethical concerns. This issue is likely to grow, as neurotechs will increasingly benefit from wireless technologies, which are susceptible to suffering from unauthorized access and to compromising the good functioning of the device. Furthermore, it is possible that brain data could be collected without consent, or under coercion, among others for surveillance purposes and "neuroprofiling", as the NeuroRights Foundation underlines in a report.

The next question regards **ownership** of this data: is it owned by the users of these technologies, by those who collect it, or by the manufacturers of the devices? Clinical research protocols can be strictly regulated in terms of confidentiality and privacy, but these standards are not universal, and change from research to standard of care. Some researchers "would like to see brain data treated like transplant organs – carefully tracked and with a ban on any profit-making, [or at least] protected like medical information." Crucially, direct-to-consumer neurotechs **are completely unregulated**. This implies that information may be obtained illegally and may end up in the hands of those who are in not entitled to have access to it, but who have a strong interest, such as insurance companies.

"Information collected [...] from neuro-devices can be obtained and used to identify someone, or reveal their brain activity, particularly where this indicates a stigmatizing neurological or mental health condition or could otherwise be used for **discriminatory purposes**", says a UNESCO report on neurotechnology. In the case of employees having consented to monitoring by their employers (see Case 2), the balancing act lies between the appropriateness of using these surveillance methods and the possibility of interpreting this information for other purposes without the employees' knowledge; today, these possibilities are scarce, but such systems can become reliable, at which point the data can become usable and profitable.

With the advent of home-based neuro-devices (Case 3), potentially managed remotely by the companies that make them, these data protection issues become even more relevant. The *Guardian* quotes an expert drawing a parallel with the Cambridge Analytica scandal, which used the data of 87 million Facebook users without their consent to benefit Donald Trump's political campaign: "It becomes a commercial interest [when] people want to do something else with the data [...] It's bringing that whole data economy [...] right into the neuro-space, and there's potential for misuse [...] It would be naive to think authoritarian governments would not be interested. [And some] companies are trying to make a model of what a person is so that that can be **exploited**."

## 2.2 On identity

"I will wake up one morning and the world will be quiet... I'm not distracted, I can focus. TMS didn't just saved my life, it gave me the chance of a livelihood. The future of TMS is the future of me. [But] there's an important discussion to be had [...]: you are playing with the **fabric of who you are as a person**." The testimony of this patient treated with TMS (see Case 5) reveals one possible impact of neurotechnology on personal identity, or an individual's capacity to think and feel by and for themselves. Such impacts are very likely to grow with more widespread use of neurotechnologies. For example, patients receiving DBS for Parkinson's disease or epilepsy (see Case 4) report effects on their mood, behavior, and social interactions, to the point of **wondering if they are still themselves**: "You kind of feel artificial," one patient told researchers quoted in the *NY Times*, which explains: "The machine isn't implanting ideas in their minds [...] but it is seemingly changing their sense of self. What happens if people are no longer sure if their emotions are theirs, or the effects of the machines they're connected to?" A philosopher describes an epilepsy patient with implanted electrodes as having "a *de novo* identity, a symbiosis of machine and mind", and argues that the removal of DBS electrodes from a patient with depression would "arguably [be] a violation of human rights".

Another impact to human identity comes through **memory modification**: the ability to manipulate memory function (Case 4) could alter an individual's personhood. "Memory for life events bridges individual memories into a coherent narrative that guides goal-directed behavior and social interactions, and therefore lies at the heart of our identity [...] Memory enhancement will [therefore] deeply affect the **construction of individual** and **collective identity**, and possibly lead to **new forms of personality** and potentially irreversible personality", concludes a brief by GESDA. The problem might "arise when this choice of memory content is imposed by a third party and the person can no longer relate to who they were before. Their perception of what they have experienced in the past is distorted and their responsibility may appear different, which affects personal identity and authenticity," underlines the UNESCO report. This argument is the basis of the recent science-fiction TV series *Severance*, in which a sinister biotech corporation uses a techno-medical procedure to separate the non-work memories of some of their employees from their personal work memories. The UNESCO report concludes that "it is possible that when connecting brains to computers, an individual's identity can become diluted, in part because algorithms will help them make decisions and can consequently blur the participation of the individual-self. Thus, we need to preserve individuals' control over decision-inducing neurotechnology."

## 2.3 On the sense of agency and responsibility

Neurotechnology represents a unique opportunity to modulate the **sense of agency**, or the feeling of being in control of one's thoughts, actions and their consequences. Simple electrodes placed behind the ears can control the direction a person walks by influencing his/her spatial perception. The improvement of BCIs allows patients to develop a sense of agency over the actions of robotic arms, for example. Invasive and non-invasive interventions could also modulate the sense of agency (see Case 7). "Technological developments mean that we are on a path to a world in which it will be possible to **decode people's mental processes** and directly manipulate the brain mechanisms underlying their intentions and decisions," says a group of worried neuroscientists. This could be used to improve BCIs for augmented patients and healthy users. Such advances could also interfere with the sense of agency, giving a person the feeling that he/she was at the origin of an action while he/she was not, or diminishing this feeling for something he/she actually did. This could lead to a potential military misuse: decreasing the sense of agency in soldiers who control weapons and potentially kill people, as imagined in 2016 in the science fiction series *Black Mirror*.

According to the UNESCO report, deep brain stimulation (DBS) "can pose a threat to an individual's [...] authentic self. If the body regains appreciable autonomy in its movements, the mind can be disoriented by the active presence of the technical device. The individual experiences a feeling of alienation [in which] the control exerted by the DBS is experienced as a form of **subjugation** [to the device which] can be controlled remotely by a clinician, and this perhaps, without the patient's knowledge."

Finally, constant monitoring of an individual's brain activity could eventually determine not only their sense of agency over a particular action, but also their **intention** behind the action: a characteristic that could be used for prosecution purposes in court.

## 2.4 On cognitive liberty (freedom of thoughts and free will)

"Freedom of thought in the normative sense is protected by the Universal Declaration of Human Rights [...] Everyone has the right to freedom of thought, conscience and religion [...] Cognitive liberty protects the sphere of thought even prior to any externalization or manifestation of thought through speech, writing, or behavior. As such [it] is chronologically antecedent to any other freedoms," according to neuroethicists. "Neurotechnology raises fundamental human rights challenges that were never envisioned by today's international human rights treaties", asserts the NeuroRights Foundation. How might these rights be imperiled by neurotechs? The answer comes at various levels.

Neuromarketing might be the first, which raises ethical dilemmas, as underlined by the International Neuroethics Society. External neurotechnologies (Case 2 & 3) are used to measure individuals' sensorimotor, cognitive and affective responses to, and engagement with, products, in order to create more effective marketing campaigns. A team demonstrated last year that "it is possible to **predict individual preferences** based on how a person's brain responses match up to others. This could potentially be used to provide individually-tailored media content". According to some experts, the push to develop better non-invasive brain-reading sensors comes mostly from the neuromarketing sector, which also pleads for as little regulation as possible regarding brain-reading.

For disabled and locked-in patients (Case 1), more efficient brain-reading techniques promote the right to freedom of thoughts and free will. But these technologies also raise questions about the **value of accuracy** and the **level of trust** in the messages transmitted by these devices, such as the wish by the otherwise non-communicative patient to benefit from assisted-suicide or to disinherit his/her direct descendants.

On the much more invasive level of using optogenetics (Case 6), it has been shown on mice that it is possible to not only influence their free will to accomplish an action, but directly to **command** it – which makes a link to the sense of agency.

"Neurotechnology opens up new dilemmas for human rights, in particular for the right to freedom of thoughts as the development of new technologies could give access to brain activities from which inference about individual thoughts can be made," states the UNESCO report. "In a world of total brain transparency, who would dare have a politically dissident thought?, asks a lawyer specialized in neuroscience. Or a creative one? I worry that people will self-censor in fear of being ostracized by society, [or] that coming out will no longer be an option, because people's brains will long ago have revealed their sexual orientation, their political ideology or their religious preferences, well before they were ready to consciously share that information… I worry that we will [...] give up our last bastion of freedom, our mental privacy."

There is much more to cognitive liberty than freedom of thoughts. There is, for example, the issue of "**neuronormativity**": the idea that there is a "normal" or "natural" way brain functioning. Anyone who differs from this norm would be considered "abnormal" or "pathological". Persons with autistic traits do not perceive and react to the world as most people do, hence they are often marginalized. Each society establishes different norms, and this should be taken into account when creating cognitive liberty rights. This also applies to people with epilepsy, anxiety, and depression (see Case 4 & 5), among others, who may refuse treatment, but still need to be integrated into society. Such questions are already being discussed, but get even more urgent when it comes to neurotechnologies, which can already detect characteristics of perception and cognition, and conditions like autism from fMRI data (see Case 3) analyzed with AI-driven algorithms.

## 2.5 On equity

Neurotechnologies are linked to the issues regarding the fundamental right to access to health. They are also uniquely embedded in the issue of human augmentation.

Healthy individuals already enhance themselves physically and mentally, using technologies and tools to go faster and beyond natural evolution (e.g., cars, cellphones: with the development of consumer-level neurotechnologies, some people might have access to memory enhancement**, neuroprostheses**, or **increased cognitive, perceptual** or **motor abilities**. This will likely increase social inequalities and lead to differences in access to better education (see Case 2), job opportunities, social interactions, and physical performance, leading to the creation of a new "**cognitive elite**". Since technology is not equally accessible to everyone, this raises the question of determining a right of access to neurotechnologies that allow for treatment and enhancement.

The cost of neurotechnologies will exacerbate existing **social inequalities** and may create new ones. Brain data could be used to discriminate against individuals for insurance and work, creating unprecedented social inequalities based on previously invisible individual characteristics (see Case 3). Society could organize itself around these enhancements, creating a societal and cultural pressure for human augmentation, with the use of neurotechnologies becoming the equivalent of the use of a smartphone or a computer. Therefore, it could be desirable to create a "right to access to neurotechnologies," just as a right to "access to the internet" has been (controversially) proposed.

# *3. Common consequences*

## 3.1 On standardization issues

As neurotechnology is developing quickly with an expanding interest of multi-stakeholder agents (e.g., academic, healthcare, companies, military), there is growing focus on **standardization at different levels**. This, among other things, is to allow the **inter-operability** of the many bio-sensing technologies and possible applications of all the efforts around neurotechnologies, and to ensure these devices are **safe**, while also bearing **intellectual property** issues in mind. A roadmap has been proposed by the IEEE Standards Association, focusing on sensor and stimulator technologies, data management, user needs, performance assessment, inter-operability with other technologies (robotics, internet, etc.), and terminology, and rating their existing level of standardization. It concludes that "the community should consider the possibility of defining complementary standards that scale-up from consumer to clinical applications. Under this approach, standards for neurotech consumer products will be more accessible, allowing the fast development required for commercial viability, without compromising on their efficacy. Gradually, more stringent standards could be adopted or developed in order to respond to the requirements of clinical applications."

## 3.2 On commercial ethical regulation issues

Second Sight Medical Products, which manufactures "bionic eyes", recently announced that it is on the verge of bankruptcy, and abandoned its technology, which is currently being used by around 350 patients... Something similar almost happened to brain implant manufacturer NeuroVista, but its implants could be taken out. The issue of "**explantation**" or maintenance of a brain implant, is of growing concern. Among other issues, it calls into question the **responsibilities** of the device makers, insurances and governments, and "makes experts in the field worry that the industry is still an unregulated Wild West, with the risk that will go down the same privacy-invading, manipulative path taken by social media", as *Science|Business* sums up.

In late 2019, the OECD published recommendations on responsible innovation in neurotechnologies, including considerations on their commercial aspects. And in summer 2021, the UNESCO International Bioethics Committee issued a report noting that there were "few regulations on neurotechnology outside of regulation on medical devices". In June 2021, a group of neuroscientists, writing in *Nature Biotechnology,* urged the private sector to address this question. "But since then, there hasn't been any significant progress, either on the corporate or public side", said a member of this group in December 2021. To her, this is in part a "deliberate" move by hands-off legislators who want to see neurotechnology grow into a profitable new market, reports *Science|Business*: "Innovation is an explicit aim of [...] the US BRAIN initiative, and the EU's Human Brain Project. The risk is that regulation will therefore only harden up after a "techlash" against neurotech from the public. Neurotech is no different from social media governance that encouraged innovation to develop relatively freely while potential ethical quandaries were left to the downstream future."

For the authors of the *Nature Biotechnology* article, "effective governance must focus on the private sector as a central actor early and requires a new set of policy perspectives and collaborative tools. These tools must complement existing efforts in public-sector research ethics, post hoc product regulation and corporate social responsibility. They must also reflect the growing recognition that we cannot rely on industry self-regulation alone to steer innovation activity in socially desirable directions." That said, they acknowledge that it is not a lost case: "A range of neurotech companies are actively seeking guidance and developing their toolkits to bridge structural constraints and the apparent need for greater public oversight. What is more, many leading neurotech companies have a strong interest in publicly demonstrating responsibility and integrity, recognizing that the entire nascent sector can be harmed by single irresponsible actors in the field."

## 3.3 On military use

Many applications of neurotechnologies have dual use, and therefore in addition to civilian have military applications. This raises particular challenges because of the vulnerability of the military in a hierarchical setting. Two uses are most obvious.

The first is enhancement of the cognitive, emotional and physical capacities of soldiers. In 2016, a US research team showed that tDCS (see Case 5) could enhance the multitasking capabilities of drone operators. Earlier work had shown that tDCS increased military target analysts' vigilance more than caffeine, and helped soldiers spot snipers more quickly in virtual reality training programs. The second is the use of invasive and non-invasive BCIs to operate tools and weapons. The authors of a 2020 book by the RAND Corporation note that "those technologies are likely to have practical use on a future battlefield. [They] could enhance the speed of communication, improve common situational awareness, and allow operators to control multiple technological platforms simultaneously." For example, with US military funding, the company Synchron is developing robotic arms and legs for injured soldiers, operated by chips implanted in their brains. And in a 2015 lab trial using a simplified flight simulator, a quadriplegic woman used a similar brain implant to control a F-35 fighter jet (see Case 1) through the power of her thoughts only. According to an expert at the Geneva Centre for Security Policy (GCSP), "the interaction between pilots and drones was improved by not only allowing the pilot to send but also receive signals from the controlled crafts." Expert reports even mention brain-to-brain communication technologies which could be used by soldiers to exchange information by "telepathy". Early research linked the brains of three rats to collectively move an avatar arm, and those of two human patients to exchange simple data. This work remains at very early stage, but it "clearly warrant[s] more research", concludes a 2021 systematic review article.

The second is that neurotechnologies could also be used therapeutically, to treat veterans with post-traumatic stress disorder (PTSD) or mood disorders, or to increase their resilience to stress. Finally, as the GCSP expert notes, a category of use "comprises neurotechnological systems for deception detection and interrogation capable of accessing concealed information in response to a stimulus. Medical diagnostics techniques such as functional magnetic resonance (fMRI) and electroencephalography (EEG) can here also be used as interrogation tools." (see Case 3)

Government research agencies are investing heavily in neurotechnologies. The US Defense Advanced Research Projects Agency has already "demonstrated achievements such as neural control of prosthetic limbs and restoration of the sense of touch to the users of those limbs," relief of otherwise intractable neuropsychiatric illnesses such as depression, and improvement of memory formation and recall. And in 2019, it launched a program to "pursue a mix of approaches to developing wearable interfaces for communicating with the brain. And as the *Guardian* reports, "the US Bureau of Industry and Security released a memo [in October 2021] on the prospect of limiting exports of BCI technology from the US. Acknowledging its medical and entertainment uses, the bureau was concerned it may be used by militaries to improve the capabilities of human soldiers and in unmanned military operations". "Although BCI applications are currently still in the basic-research phase, development of other technologies by the military, including robotics, AI, and big data analysis, will need to consider the eventual availability of BCI", concludes the RAND book.

## 3.4 On justice

Like genetics before it, neurotechnology with likely provide tools applicable to the legal system, and the contributions of neuroscience to law gaining more interest, as reported in a French colloquium on the topic. Neuroscience is already used to assess mental capacities. It could be used to force to bring a suspected criminal to confession. "Ethical dilemmas arise when we think about brain imaging techniques that could make it possible to tell when someone is lying, or make assumptions about sanity or guilt in criminals with different brain characteristics", underlines the International Neuroethics Society. In the Human Rights Declaration as written today, "the use of a non-invasive BCI to observe and record a detainee's brain activity, such as to verify guilt or innocence by triggering the detainee's instant recall, may not violate mental 'liberty and security' so long as there is no injury. Particularly where neurotechnology can read all brain activity, the State will have unfettered access to detainees' and suspects' brains, likely resulting in excessive pretrial detention and numerous due process violations", the NeuroRights Foundation writes in its report.

It could also have an impact on the judgement of criminal acts by analyzing the memories of victims and defendants or by establishing personality profiles; memory modification could be used in victims or criminals in the case of traumatic offenses; and brain modulation could be used to prevent criminal behaviors. These possibilities also raise ethical questions related to data privacy, identity, agency and cognitive liberty.

Neurotechnologies can therefore help the functioning of justice, but also create new challenges for it. Implants and machines controlled directly by recorded brain signals, with minimal intervention by their user, will blur the demarcation between the self and the machine, and could diminish human responsibility and hinder accountability. How will judges determine culpability in crimes committed by users of neuroprosthetics who say they were not in control of their actions? Should we create devices that censor any brain command that could lead to undesirable or criminal actions? Such questions are already posing a problem for autonomous cars.

## 4. Conclusion

Today, interfaces implanted in the brain help disabled people communicate and move again, in the lab and in the clinic, by stimulating specific brain regions. Other interfaces, placed on the skull, can "read" brain states and mental images, in the lab, the clinic and increasingly for all consumers.

Tomorrow, the loop between interfaces that read and those that write (stimulate) the brain will be closed, opening the way to treat mood or personality disorders, to increase cognitive functions, to control behavior in a precise manner.

Neurotechnology is therefore an exciting emerging technology, with broad and deep impacts on human beings and society. "Brain data" from individuals require privacy protection, but also sharing research purposes; neurotechnological treatments will affect your memory, your personality, your identity, modify how we perceive being in control and responsible; it challenges our ideas of freedom of thoughts, trust, free will, and what it is to be "normal". In addition, equitable access to these liberating technologies, the prospect of dual use (weaponization), the definition of the ethical responsibilities of the device makers are challenges that neurotechnology will pose to all in the future.

A permanent and anticipatory conversation between neurotechnologists (public labs and industry), decision makers (diplomats, UN agencies, governments) , and society at large is the best way forward.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# The NeuroTech Compass – Solution idea III

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gesda
GESDA Solutions

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## Challenge to tackle

Rapid advancements in the field of neurotechnology suggest that **interventions in** and **on** the **brain** using **direct interfaces** with **computers** (brain-computer interfaces, BCI) could lead to their **use** in **treating neurologic disorders** and even enhance brain functions in **healthy people.** These anticipated developments will offer **great potential** for health, communication, mood regulation, memory and physical capability.
Applications are also **rapidly developing beyond the medical field** such as in neuromarketing, gaming and entertainment, as well as in the military domain. Neurotechnologies generally have a positive impact but **can raise ethical, societal, economic, and legal concerns**, mainly when applied outside of the research and clinical setting. With the scientific and technological landscapes rapidly accelerating, a global approach to effectively govern these developments **remains a challenge**

## Solution idea in a Tweet

A **NeuroTech Compass** to **support decision-makers** by providing a **navigation tools** to **enable research** in neuroscience and neurotechnology and their **applications** in society

## Pilots/Initiative

- **Norms & Principles for neurotechnologies** (TBD)
- **Matrix on one use case** (TBD)

## Solution idea key elements

The **NeuroTech Compass** will be a **pro-active convening space**, where available information are continuously updated to remain relevant, aiming at identifying the science and diplomacy conditions of success for global impact allowing actors to build **collective intelligence** to reach common objectives
The **NeuroTech Compass** (NTC) is based on **three pillars**:

- **Information**, **continuous data collection** on current and anticipated **neurotechnology** with a repository of use cases.
  The NTC will seek **direct engagement** with **communities of practice** to detect weak signals of the scientific pipeline
- **Analysis**, *systematic crossing* of *anticipated breakthroughs* with *existing* or *proposed regulations*, national or international, soft or hard law, and with the Human Right framework.
  The analysis will take the shape of a *tool* (the "Matrix") proposed for *use* to *stakeholders* and *decision makers*, enriched by inputs from *direct engagement with communities of practice* (alarm signals, and elaboration of norms)
- **Intelligence to act**, as *honest broker*, the NTC will provide a *convening space* between *technologists* (public and private) and *decision makers* (national and international) to help the parties *navigate* their *desired paths*, to *translate knowledge* into *policy options*, to help *governments* and *international organizations harmonize priorities*, to provide a space for anticipatory governance.
  The NTC will be *proactive* in this *convening activity*, which will take the shape, i.a., of a regular Geneva Forum (probably linked to the GESDA summit).

## Type of Solution idea

- [x] Governance
- [ ] Knowledge
- [ ] Innovation

## Anticipation

**Anticipation Timeline**

5 years — **10 years** — 25 years

**Anticipatory Science**

| | |
|---|---|
| 1. Quantum Revolution and Advanced AI<br>**SAB 1** SAB 2 | **2. Human Augmentation**<br>**SAB 3** **SAB 4** |
| 3. Eco-regeneration & Geoengineering<br>SAB 5 SAB 6 | 4. Science & Diplomacy<br>**SAB 7** SAB 9<br>SAB 8 **SAB 10** |

## Involved SDGs