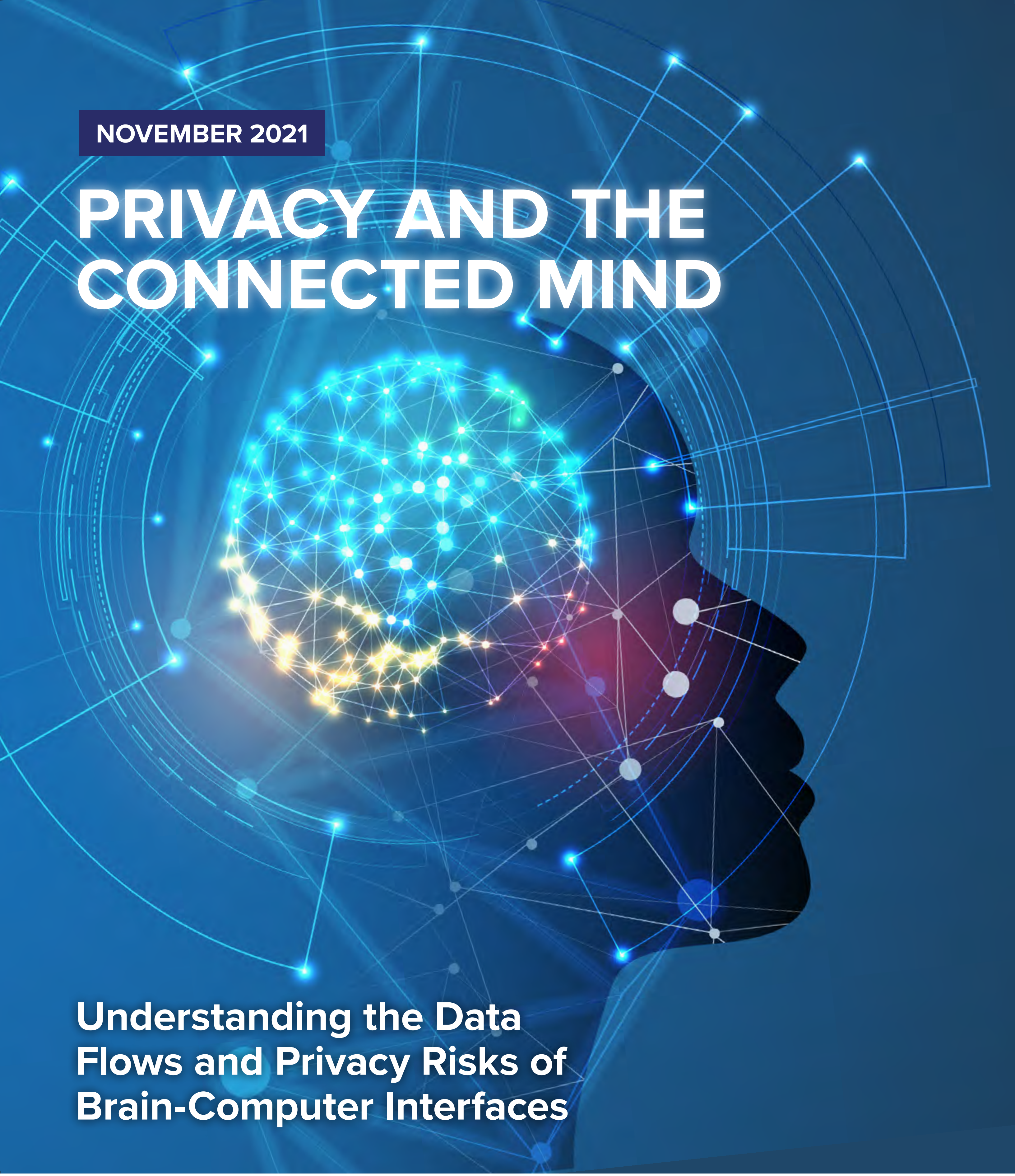

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PRIVACY AND THE CONNECTED MIND

Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces

FUTURE OF PRIVACY FORUM

IBM

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EXECUTIVE SUMMARY

This report provides an overview of the technology, benefits, privacy and ethical risks, and proposed recommendations for promoting privacy and mitigating risks associated with brain-computer interfaces (BCIs). BCIs are computer-based systems that directly record, process, or analyze brain-specific neurodata and translate these data into outputs that can be used as visualizations or aggregates for interpretation and reporting purposes and/or as commands to control external interfaces, influence behaviors, or modulate neural activity. While neurodata can take many forms, this report discusses "neurodata" as data generated by the nervous system, which consists of electrical activity between neurons or proxies of this activity. Personal neurodata refers to neurodata that is reasonably linkable to an individual.

BCI devices can be either invasive or non-invasive. Invasive BCIs are installed directly into—or on top of—the wearer's brain through a surgical procedure. Today, invasive BCIs are typically used in the health context. Non-invasive BCIs rely on external electrodes and other sensors or equipment connected to or monitoring the body for collecting and modulating neural signals. Consumer-facing BCIs use various non-invasive methods, including headbands.

Some BCI implementations raise few, if any, privacy issues. For example, individuals using BCIs to control computer cursors might not reveal any more personal information than typical mouse users, provided BCI systems promptly discard cursor data. However, some uses of BCI technologies raise important questions about how laws, policies, and technical controls can safeguard inferences about individuals' brain functions, intentions, moods, or identity. These questions are increasingly urgent in light of the many potential applications expanded use of BCIs in:

- **Healthcare** – where BCIs could monitor fatigue, diagnose medical conditions, stimulate or modulate brain activity, and control prosthetics and external devices.
- **Gaming** – where BCIs could augment existing gaming platforms and offer players new ways to play using devices that record and interpret their neural signals.
- **Employment and Industry** – where BCIs could monitor workers' engagement to improve safety during high-risk tasks, alert workers or supervisors to dangerous situations, modulate workers' brain activity to improve performance, and provide tools to more efficiently complete tasks.
- **Education** – where BCIs could track student attention, identify students' unique needs, and alert teachers and parents of student progress.
- **Smart Cities** – where BCIs could provide new avenues of communication for construction teams and safety workers and enable potential new methods for connected vehicle control.
- **Neuromarketing** – where marketers could incorporate the use of BCIs to intuit consumers' moods and to gauge product and service interest.
- **Military** – where governments are researching the potential of BCIs to help rehabilitate soldiers' injuries and enhance communication.

This report focuses on the current privacy impacts of BCIs, as well as the data protection questions raised by realistic, near-future use of BCIs. While the potential uses of BCIs are numerous, BCIs cannot at present or in the near future "read a person's complete thoughts," serve as an accurate lie detector, or pump information directly into the brain. It is important for stakeholders in this space to delineate between the current and likely future uses and far-off notions depicted by science fiction creators, so that we can identify urgent concerns and prioritize meaningful policy initiatives. We take seriously the concerns raised by futuristic potential developments and keep them in mind as we make recommendations, but in this paper we focus on the immediately pressing need to address issues already faced and likely to be faced in the upcoming decade.

Although the report primarily focuses on the privacy concerns—including questions about the transparency, control, security, and accuracy of data—involving existing and emerging BCI capabilities, these technologies also raise important technical considerations and ethical implications, related to, for example fairness, justice, human rights, and personal dignity.[1] These concerns are equally critical and complex, so this report highlights where additional ethical and technical concerns emerge in various use cases and applications of BCIs. Greater in-depth discussion of areas beyond privacy warrant additional research and careful consideration, and we hope to turn to those issues in future efforts.

To promote privacy and responsible use of BCIs, stakeholders should adopt technical guardrails including:

- Providing on/off controls when possible—including hardware switches if practical;
- Providing users with granular controls on devices and in companion apps for managing the collection, use, and sharing of personal neurodata;
- Providing heightened transparency and control for BCIs that specifically send signals to the brain, rather than merely receive neurodata;
- Designing, documenting, and disclosing clear and accurate descriptions regarding the accuracy of BCI-derived inferences;
- Operationalizing industry or research-based best practices for security and privacy when storing, sharing, and processing neurodata;
- Employing appropriate privacy enhancing technologies;
- Encrypting personal neurodata in transit and at rest; and
- Embracing appropriate protective and defensive security measures to combat bad actors.

Stakeholders should also adopt policy safeguards including:

- Ensuring that BCI-derived inferences are not allowed for uses to influence decisions about individuals that have legal effects, livelihood effects, or similar significant impacts—e.g. assessing the truthfulness of statements in legal proceedings, inferring thoughts, emotions or psychological state, or personality attributes as part of hiring or school admissions decisions, or assessing individuals' eligibility for legal benefits;
- Employing sufficient transparency, notice, terms of use, and consent frameworks to empower users with a baseline of BCI literacy around the collection, use, sharing, and retention of their neurodata;
- Engaging IRBs and other independent review mechanisms to identify and mitigate risks;
- Facilitating participatory and inclusive community input prior to and during BCI system design, development and rollout;
- Creating dynamic technical, policy, and employee training standards to account for the gaps in current regulation;
- Promoting an open and inclusive research ecosystem by encouraging the adoption, where possible, of open standards for neurodata and the sharing of research data under open licenses and with appropriate safeguards in place. A similar open-skills approach could also be considered for a subset of direct-to-consumer BCIs; and
- Evaluating the adequacy of existing policy frameworks for governing the unique risks of neurotechnologies and identifying potential gaps prior to new regulation.

Key Terminology and Definitions

- **Neurodata** - Data generated by the nervous system,[2] which consists of the electrical activities between neurons or proxies of this activity.
- **Personal Neurodata** - Neurodata that is reasonably linkable to an individual.
- **Neurotech/Neurotechnology** - Technology that collects, interprets, infers or modifies neurodata.
- **Brain-Computer Interface (BCI)** - Computer-based systems that directly record, process, or analyze brain-specific neurodata and translate these data into outputs that can be used as visualizations or aggregates for interpretation and reporting purposes and/or as commands to control external interfaces, influence behaviors, or modulate neural activity.

INTRODUCTION

Brain-computer interfaces (BCIs) are a prime example of an emerging technology that is advancing new areas of human-machine interaction. Today, BCIs are primarily used in the healthcare context for purposes including: rehabilitation, diagnosis, symptom management, and accessibility. While BCI technologies are not yet widely adopted in the consumer space, there is a recent interest and proliferation of new direct-to-consumer neurotechnologies. The emergence of such technologies across various sectors poses numerous benefits and raises significant questions about user privacy.

When connected to the Internet,[3] BCIs can be classified as a type of wearable or implanted instrument within the Internet of Bodies, a network of devices connected to, and generating information from, the human body.[4] Such communication has long been supported by various interfaces, from the keyboard and mouse to touchscreens, voice commands, and gesture interactions. As computers become more integrated into daily human experience, new ways of commanding computer systems and experiencing digital realities have gained in popularity, with novel uses ranging from gaming to education.

While BCIs offer benefits from improving patient health outcomes to providing more immersive and customizable education, training, and entertainment, the technologies raise many of the same risks posed by digital home assistants, medical devices, and wearables. New and heightened risks associated with privacy of thought also emerge, resulting from recording, using, and sharing of a variety of neural signals.[5] According to a recent report, consumers list privacy and security as major concerns regarding neural interfaces, second only to product safety.[6] Sometimes, BCIs must always be on in order to function properly—particularly in the health and medical context. Always-on tech can collect more information than users expect, particularly when individuals are not provided sufficiently clear and detailed notice prior to consent. This report explores how BCIs fit into the broader scheme of next-generation interfaces, and suggests safeguards to mitigate potential privacy and security risks.

Because of the emerging-nature of BCIs, it is important to consider both current and future-facing privacy and ethical risks based on technical capabilities, use cases, and the current understanding of neurodata. Along with identifying what neurodata and personal neurodata are collected by BCIs and what conclusions or inferences are drawn based on this data, it is equally important to specify what BCIs cannot achieve, especially given the current hype cycle surrounding technologies that can easily veer into unrealistic, sci-fi territory. At the moment, BCIs cannot read an individual's precise thoughts, accurately determine whether someone is telling the truth or lying, or directly pump knowledge or skills into an individual's brain or make someone "smarter." While these capabilities could exist in the future and warrant discussion and debate, they are far attenuated from current realities. This report appreciates the importance of such discussions, but seeks to focus on the current—and likely, near-term—capabilities of BCIs discussed in this report.[7]

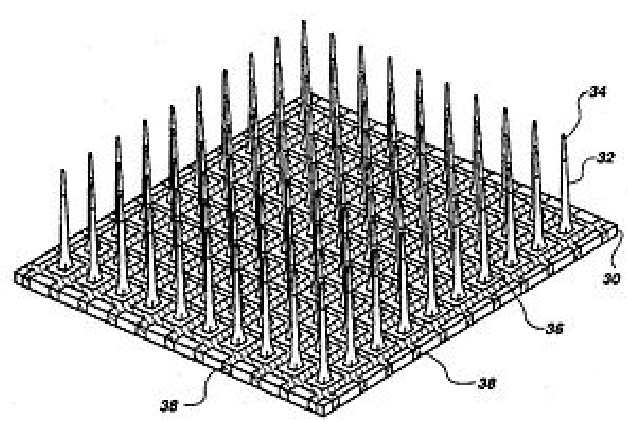
Part I: BCIs are Devices that Can Both Record and Modulate an Individual’s Brain Signals Through the Collection and Processing of Neurodata

A. BCIs are Computer-Based Systems that Record, Modulate—or Both Record and Modulate—Electrical Brain Signals, Which Can Be Translated Into Outputs

BCIs are computer-based systems that directly record, process, or analyze brain-specific neurodata and translate these data into outputs that can be used as visualizations or aggregates for interpretation and reporting purposes and/or as commands to control external interfaces, influence behaviors, or modulate neural activity. BCIs can be broadly divided into three categories: 1) those that record brain activity; 2) those that modulate brain activity; and 3) those that do both, also called bi-directional BCIs (BBCIs).[8] BCIs that record brain activity are more commonly used in the healthcare, gaming, and military contexts. Modulating BCIs are typically found in the healthcare context. For example, modulating BCIs are used to treat Parkinson’s disease and other movement disorders by using deep brain stimulation to treat the rigidity, slowness, and resting tremors common in Parkinson’s patients.[9] While BCIs technically refer to devices that directly record or modulate the brain, other related neurotechnologies indirectly record and modulate. One of the most successful examples of indirect stimulation is cochlear implants, which help restore hearing and suppress tinnitus by modifying the information that is provided to a compromised auditory system.[10] BBCIs, which both record and modulate, can be an especially useful rehabilitation tool for spinal injuries or strokes.[11]

B. BCIs Can be Invasive or Non-Invasive and Employ a Number of Techniques for Collecting Neurodata and Modulating Neural Signals

BCIs can be invasive or non-invasive.[12] Invasive BCIs are installed directly into—or on top of—the wearer’s brain through a surgical procedure. Today, invasive BCIs are used in the health context. For example, invasive clinical BCI implants have been used to improve patients’ motor skills.[13] Invasive BCI implants can involve a number of different types of implants. An electrode array called a Utah array is installed into the brain and relies on a series of small metal spikes set within a small square implant to collect or modulate brain signals. New innovations like neural lace and neural dust are meant to drape over or be inserted into multiple areas within the brain.[14]



Utah array. Image courtesy Wikipedia.

Other prominent examples of invasive BCIs rely on electrocorticography (ECoG), in which electrodes are attached to the exposed surface of the brain to measure electrical activity of the cerebral cortex. ECoG is most widely used for helping medical providers locate the area that is the center of epileptic seizures. This detection helps facilitate more targeted medical treatment but does not constitute medical treatment itself.[15]

In April 2021, Neuralink—Elon Musk's startup centered around creating a minimally invasive BCI—released a video of a macaque monkey playing a videogame using an invasive BCI.[16] Explaining Neuralink's invasive BCI prototype, "in a lot of ways," Musk said, "it's kind of like a Fitbit in your skull, with tiny wires."[17] While the Neuralink device is still in the prototype stage, the technology points to a possible future where invasive BCIs are used for commercial purposes, such as gaming, entertainment, education, and wellness. Today it seems unlikely that consumers would be willing to surgically implant a device into their brain for commercial enjoyment, cognitive monitoring, education, and other direct-to-consumer uses, but only time will tell whether invasive BCIs for commercial purposes will eventually become mainstream.

Unlike invasive BCIs, non-invasive BCIs do not require surgery. Instead, non-invasive uses of BCI-technology rely on external electrodes and other sensors for collecting and modulating neural signals.

An example of a non-invasive EEG-fitted BCI device.

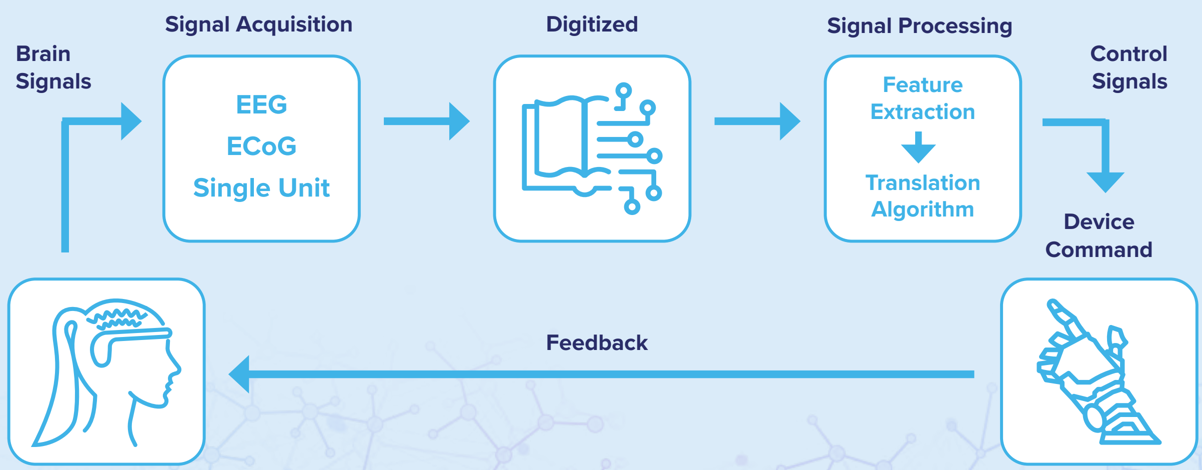
One of the most prominent examples of a non-invasive BCI technology is an electroencephalogram (EEG)—a method for recording electrical activity in the brain, with electrodes placed on the surface of the scalp to measure the activity of neurons in the brain.[18] EEG-based BCIs are common in the gaming space in which collected brain signals are used to control in-game characters and select in-game items. Another noteworthy non-invasive method is near-infrared spectroscopy (fNIRS), which measures proxies of brain activity via changes in blood flow to certain regions, specifically changes in oxygenated and deoxygenated hemoglobin concentrations using near-infrared light.[19] fNIRS is especially prominent in wellness and medical BCIs, such as those used to control prosthetic limbs.[20]

Other non-invasive techniques go beyond simply recording neurodata by also modulating the brain, which is one reason the term "non-invasive" is fairly contentious, with researchers and scientists finding the line between invasive and non-invasive uses of BCIs difficult to draw. For example, can a device that modulates a brain in a closed-loop fashion—meaning that neurodata recorded by the BCI serves as an input in how the BCI stimulates the user's neural signals—ever truly be non-invasive? What about a device that is not implanted surgically, but still carries the potential for stimulation? For instance, transcranial direct current stimulation (tDCS)[21] and transcranial magnetic stimulation (TMS)[22] are both used to modulate neuroactivity in various areas, including the frontal lobes. Researchers have proposed that these forms of stimulation may increase memory, and learning abilities; however, such claims are still under review.[23] Non-invasive neurotechnologies should not be equated to non-harmful technologies—just because a device is not directly implanted to sit on or within the human brain does not mean that device does not pose unique health and other privacy and data use risks.[24]

BCIs are generally characterized by four components:[25]

- **Signal Acquisition and Digitization:** involves sensors (e.g. EEG, fMRI, etc.) measuring neural signals. The device amplifies signals to levels that enable processing and sometimes filters collected signals to remove unwanted data elements, such as noise and artifacts. These signals are digitized and transferred to a computer.
- **Feature Extraction:** As part of signal processing, applicable signals are separated from extraneous data elements, including artifacts and other undesirable elements.
- **Feature Translation:** Signals are transformed into usable outputs.
- **Device Output:** Translated signals can be used as visualizations for research or care, or they can be used as directed instructions, including feedforward commands utilized to operate external BCI components (e.g. external software or hardware like a robotic arm) or feedback commands which may provide afferent (conducted inward) information to the user or may directly modulate on-going neural signals.

An example of these components can be found in the following figure.



While the focus of this report is technologies that record or influence neurodata from the brain, neurodata is also found throughout the nervous system (including from the spinal cord and peripheral nervous system) and thus similar but non-BCI neurotechnologies are being developed that capitalize on these downstream signals. Other invasive and non-invasive techniques include indirectly collecting neurosignals sent from the brain with sensors placed on other parts of the human body. For instance, an electromyography (EMG) sensor is a neurotechnology that can be worn non-invasively as a wristband[26] or inserted into the human body to indirectly record motor neurons and their electrical activity in muscles.[27] Today this method is typically used to diagnose neuromuscular abnormalities, but future use cases point to using EMG for detecting an individual's intent to move fingers and other appendages for operating virtual keyboards and other devices.[28]

A Timeline of Interfaces[29]

- **1924** — First Human EEG Recorded
- **1952** — First Voice Interface
- **1968** — First Virtual Reality Headset
- **1969** — First Successful Cochlear Implant
- **1973** — The Term "Brain-Computer Interface" is Coined
- **1973** — First Computer Mouse is Commercially Available
- **1982** — First Multi-Touch Touchscreen
- **1998** — First Invasive BCI That Produces High-Quality Signals
- **2005** — First Person to Control an Artificial Hand Using BCI
- **2012** — Paralysis Patients Control Robotic Arms Using BCI
- **2016** — First BCI to Restore Sensation to a Paralyzed Person
- **2018** — BCI Provides Rudimentary Vision to a Low-Vision Patient
- **2019** — Signals from an Invasive BCI are Accurately Decoded Into Text with an Error Rate as Low as 3% When Tested On Vocabularies Up to 300 Words
- **2021** — A Paralyzed Man Uses a BCI to Type with His Thoughts

C. Recorded Neurodata Becomes Personal Neurodata When It is Reasonably Linkable to an Individual

Neurodata is data generated by the nervous system, which consists of the electrical activities between neurons or proxies of this activity. These neurons help carry out tasks, such as comprehension, movement, and communication. Neurodata can be both directly collected from the brain, or indirectly collected from an individual's spinal cord, muscles, or peripheral nerve in the form of a downstream signal from brain activity or a preparatory signal prior to brain activity.

At times, neurodata can be personally identifiable when reasonably linkable to an individual or when combined with other identifying data associated with an individual, such as when part of a user profile. Personal neurodata is neurodata that could be reasonably linkable to a particular individual.[30] The collection and processing of personal neurodata can produce information related to an individual's biology and cognitive state. Additionally, the processing of personal neurodata can lead to inferences about an individual's moods, intentions, and various physiological characteristics, such as arousal. Machine learning (ML) sometimes plays a role as a tool for helping determine if a neurodata pattern matches a general identifier or particular class or physiological state.

Although identifying individuals based solely on their collected personal neurodata is likely a difficult proposition, such identification has been shown to be possible with relatively little data (less than 30 seconds-worth) within a lab setting,[31] and some experts believe that such identification is feasible if not today, then in the near-term.[32] This possibility has implications for definitions pertaining to biometric data, as well as its permitted use. Personal neurodata can vary in levels of sensitivity, as certain personal neurodata can reveal seemingly innocuous data leading to few, if any, inferences about an individual; health information associated with an individual; or provide insight into an individual's private feelings or intentions. For example, a BCI might reveal what object a gamer intends to select in a video game,[33] which may or may not be innocuous; infer that a truck driver is becoming less alert while driving,[34] which could reveal an individual's sleeping habits; or it could reveal whether a patient is depressed, information pertaining to their health.[35]

In the future, BCIs could progress into new arenas, recording increasingly sensitive personal neurodata, leading to intimate inferences about individuals. Those arenas include transcribing a wide-range of a wearer's thoughts into text, serving as an accurate lie detector, and even implanting information directly into the brain. These uses are still in the early research phases and could be decades from fruition, or perhaps never emerge.[36]

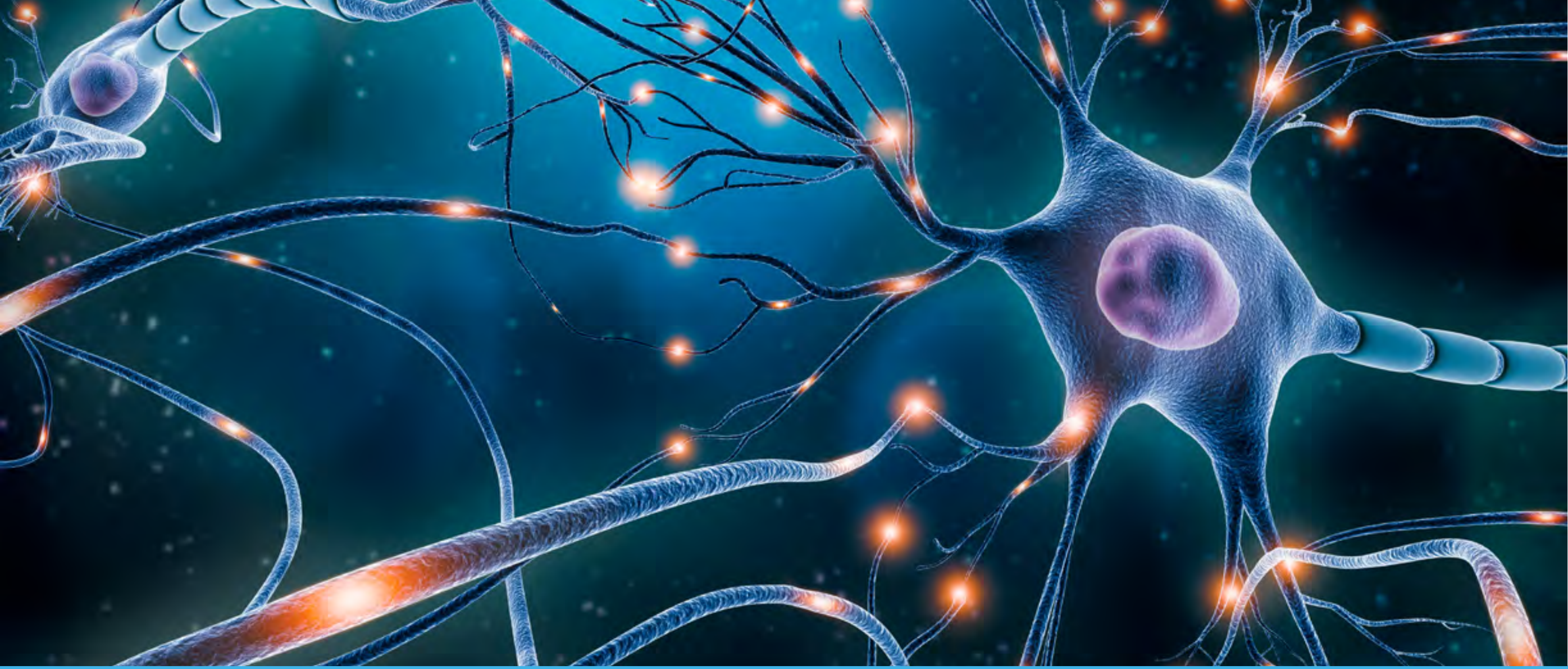
D. Both Invasive and Non-invasive BCIs Pose Technical Challenges for Effectively Recording Neurodata and Modulating Neural Signals

Regardless of the technique used, recording and processing brain signals to derive usable neurodata is a technologically challenging process. Wired BCIs—typically associated with the clinical and medical context—include complex wiring that involves a prolonged preparation time before use, while wires limit user movements.[37]

Wireless BCIs avoid some of the hardware challenges of wired BCIs, but present new challenges associated with battery life—especially in the case of health-related BCIs that are intended to be on and active for extended sessions—and device weight, comfort, and practicality.[38] Other hardware challenges include the need for commercial non-invasive headsets to record small neural signals through a physical barrier of hair, skin, flesh, and bone, all of which can interfere with the signals and add noise to the data. Meanwhile, invasive BCIs require expensive, high-risk surgery.[39]

Once signals are collected, the device must process and separate actionable nerve impulses from those that are created by passive activities, including artifacts derived from the wearer's muscle movements, eye blinking, and electrical activity from the heart. Sometimes this extra data is used in conjunction with BCIs for various purposes, but these artifacts often have to be removed for neurodata to be usable. Most neurodata derived via BCIs is noisy (especially in the case of non-invasive applications) and creating computer systems that can classify and remove noise is a complex and cumbersome undertaking.

After actionable signals are gathered and sorted, ML[40] algorithmic models can be applied for classifying neurodata. This typically involves a calibration and training process in which a user performs a number of operations so that the algorithm can understand the user's unique neural data that represent their patterns when performing various actions. Using ML systems presents its own set of preliminary challenges such as: whether these ML systems can classify data better than chance, whether a particular system is appropriate to achieve a desired outcome, or whether the system does in fact accurately conform to a user's neural signature, in addition to any ethical and legal risks. This process of identifying and processing an accurate and meaningful neural signature is something that researchers are still attempting to master.



Part II: BCIs Provide Benefits and Present Risks in a Number of Sectors Including Health, Gaming, Employment, Education, Smart Cities, Neuromarketing, and the Military

This section surveys BCI adoption across seven key sectors: health and wellness; gaming; education; employment; smart cities; neuromarketing; and the military. These sectors represent areas where consumer BCI technologies are quickly evolving, and where unique privacy concerns are most salient.[41] However, if the past is prologue, individuals and societies will find new and unexpected uses of technologies as they evolve and adapt inside and outside of these sectors.

Each sectoral use of BCI technologies examined below is accompanied by specific benefits and risks and an analysis of some of the existing laws, policies, and best practices currently in place that might safeguard neurodata within a particular sector. It is worth noting; however, that many of the benefits, risks, and challenges discussed overlap across a variety of uses and sectors outside BCIs and neurotechnologies, such as genetics, biometrics, and AI. While neurodata and BCIs may not be explicitly mentioned in current law, existing regulations may still be held to apply, even if policymakers did not contemplate the novel privacy issues associated with neurotechnologies. Conversely, new law may be motivated by the failure of existing law to contemplate novel privacy issues, such as the Genetic Information Nondiscrimination Act (GINA) arising out of a sense that contemporaneous health law—such as HIPAA—did not sufficiently contemplate or protect against issues prompted by genomic technologies.[42] Similar regulations have since been created at state and local levels in response to increasing usage of biometric data and associated risks.[43]

Regulators might recognize a similar need in connection with neurodata, leading to new laws and standards. But in the absence of amended and new regulations, developers must consider current regulations, standards, and frameworks that might apply to this evolving field or serve as a foundation for future regulation, guidance, or decision-making around BCIs. Neurotechnology-specific frameworks include: the OECD Recommendation on Responsible Innovation in Neurotechnology[44] and the FDA's recent guidance on BCIs for Patients with Paralysis or Amputation.[45] Legal frameworks of note include constitutional and fundamental rights protection of the right to respect for private life and confidentiality in some jurisdictions around the world,[46] the protection of personality rights in Civil Codes in jurisdictions as varied as Germany, Quebec and, most recently, China,[47] the EU's draft legal framework on AI,[48] as well as comprehensive data protection laws, such as the California Privacy Rights Act (CPRA),[49] the European General Data Protection Regulation (GDPR),[50] to name a few.

Although these legal frameworks do not pertain to neurotechnology specifically, given BCI's integration with AI and neurodata's overlap with biometric data conceptualization, some of this guidance may be relevant or transferable in the future.

Additionally, there are numerous international brain initiatives that are working together to not only better understand the ethical issues and risks associated with BCI technologies and other neuroscience applications, but also publish general guidance, best practices, and key research questions regarding these topics.[51]

A. Health BCIs Diagnose Medical Conditions, Modulate Brain Activity for Cognitive Disorder Management, and Promote Accessibility

Today, health BCIs can improve health diagnosis, rehabilitation, and accessibility. Current breakthroughs in diagnosis include quantifying fatigue, identifying depression, and measuring stress.[52] Diagnostic BCIs can also be especially helpful when patient responses are unavailable, such as when patients experience disorders of consciousness, including locked-in syndrome, whereby individuals are fully conscious but unable to move, speak, or explain how they are feeling.[53] Current research efforts focus on BCIs that diagnose condition progression, such as glaucoma.[54]

While diagnosis typically involves recording brain activity, health BCIs are also used to modulate patients' brains and nervous systems. Brain modulation is used in numerous ways, including stimulation for modulating and disrupting seizures for epilepsy patients.[55] Recent advances in health BCI modulation include a vision restoration study to bypass the eye and the optic nerve to feed images directly to the brain–resulting in low-resolution vision.[56]

Other than diagnosis and stimulation, BCIs can provide increased accessibility. A new generation of prosthetic limbs rely on BCIs. These neuroprosthetics, or artificial limbs, move in response to thought stimuli, including the creation of BCI-powered automatic wheelchairs.[57] A non-invasive mind-controlled wheelchair, developed by researchers at Switzerland's Federal Institute of Lausanne, can follow simple directions derived from a BCI and can assess the area around the wheelchair to navigate its surroundings safely.[58] Users of neurotech wheelchairs think of moving their left or right arm to direct their wheelchair in their chosen direction. Recent advancements involve users not needing to think of specific words like "table" in order to direct their chair to a nearby object; instead, they can think of associated activities like eating.[59] Another noteworthy example occurred in 2019 when scientists implanted a BCI into the brain of a patient who was left with minimal movement of his arms and hands after a surfing accident.[60] The invasive electrodes allowed the patient to control both left and right robot appendages to perform daily tasks, such as eating.[61] Similarly, BCIs act as tools for providing haptic feedback or haptic sensory replacement within prosthetics and exoskeletons for purposes of patient rehabilitation, regaining sensation, and an increased ability for patients to perform previously inaccessible tasks.[62]

There are also efforts to connect BCIs with smart devices and IoT (internet of things), which could aid individuals with neurological disorders or motor impairments in doing activities of daily living or interacting with various appliances and devices, enabling improved or sustained quality of life through increased accessibility within their home environment.[63]

As mentioned previously, BCIs are also starting to emerge in the commercial wellness space as a method personal tracking and improving cognitive abilities (such as attention or meditation) and mental and physical health (such as sleep quality or fatigue). This is a developing space with open questions about the efficacy of BCIs as wellness devices still up for debate.[64] Many of these wellness BCIs overlap with the gaming and toy space. The NeuroSky Mindwave Mobile 2: Brainwave Starter Kit provides the user with information about their brain's electrical impulses when relaxing and when listening to music.[65] The product includes an EEG-fitted headband and connects to companion apps via Bluetooth.[66] The device also provides training games purported to help improve meditation, attention, and enhance the user's learning effectiveness.[67] Further, the device includes tools for players to create their own brain-training games.[68]

1. Health BCI Risks Include: Security Breaches, Infringement on Mental Privacy, and Accuracy Concerns

Security breaches represent some of the most prominent risks in the health and wellness BCI space. Some of these security risks are presaged by earlier breaches of medical implantable devices. In 2017, half a million pacemakers[69] were recalled because they were vulnerable to hacking.[70] Just as pacemakers could be breached, BCIs are vulnerable to cyber risks, including breaches,[71] resulting in potentially severe physical harm to the patient. In such cases, BCIs run the risk of encountering interference—whether by bad actors or error—that might result in failed communication around high-stakes medical decisions. Recently, researchers showed that hackers, through imperceptible noise variations of an EEG signal, could force BCIs to spell out certain words that do not align with what the wearer is thinking.[72] The consequence of this security vulnerability could range from user frustration to severe misdiagnosis. Moreover, breaches of BCIs raise physical concerns around the sanctity of sensitive health information that could be captured in a hack.

An equally important risk among health-related BCIs includes sufficient and verifiable accuracy for the recording and interpreting of brain signals. High reliability of medical BCIs is especially important because inaccurate interpretation or modulation of a patient's brain could result in serious consequences, or even death. Patients relying on modulating BCIs to help mitigate cognitive disorders, such as epilepsy, could suffer grave health consequences should the BCI fail to work as intended. Additionally, patients experiencing locked-in syndrome—who might be minimally conscious—require BCIs to accurately convey a patient's wishes; concerns are particularly acute when patients rely on BCIs to communicate crucial information, such as their choices regarding treatment or even end of life decisions.[73] Accuracy is also crucial in the accessibility context, as prosthetic limbs, wheelchairs, and other devices controlled via BCIs must operate correctly and safely according to users' intentions.

Privacy risks regarding BCI accessibility devices come from the inferences drawn from conscious or unconscious intentions of an individual. The capacity of neural networks that underpin many of these devices to associate certain thoughts with directives means that subconscious or causally-connected intentions may be defined and interpreted by BCIs on a wider scale, leading to new mental privacy risks. For example, a BCI controlled wheelchair and its underlying neural network might not only deduce that the user is thinking about food, therefore directing the chair to move toward the table, but also draw other conclusions about the individual's biology and preferences, such as whether or not an individual is hungry or thirsty and at what times. These additional inferences capture new information about an individual's thoughts, intentions, or interests, many of which are related to an individual's specific biology and unique preferences.

Privacy risks are magnified when these new inferences are combined with other personal information about an individual to make decisions that impact their lives and could interfere with the autonomy afforded to individuals through the use of these accessibility BCIs. Organizations collecting and processing these brain signals, leading to granular inferences tied to an individual, could have incentive to repurpose this data for advertising or other non-medical purposes, exposing potentially sensitive biological information to third parties while running counter to individual notions of privacy. Additionally, the sharing of patient data associated with BCI use could potentially disclose an individual's previously unknown medical condition to employers, private companies, public entities, or governments.

2. Some Health BCIs are Subject to Common Rule Requirements, FCC Oversight, or International Frameworks

Some of the advancements in health BCIs involve human subject research, which in certain cases is governed by a complex regulatory framework. U.S. researchers whose projects are federally funded are typically required to obtain subjects' informed consent for data collection based on approval from a Common Rule-based Institutional Review Board (IRB) prior to undertaking studies.[74] In other instances, such as some research involving open fMRI or other open neurodata, studies might not require IRB approval when the data in question involves secondary data use of de-identified samples.

In addition, wireless IoT BCI devices are likely subject to Federal Communications Commission (FCC) oversight because of their designation as connected wearables.[75] However, given the lack of regulations around consumer wellness technologies, devices marketed outside of the physician regulated context—such as brain training games and meditation-aiding devices like Muse[76]—may lack strict oversight. For example, the Health Insurance Portability and Accountability Act (HIPAA) regulates covered entities—such as physicians and health insurers—that collect, use, process, and share health information, but does not usually apply to wellness device companies.

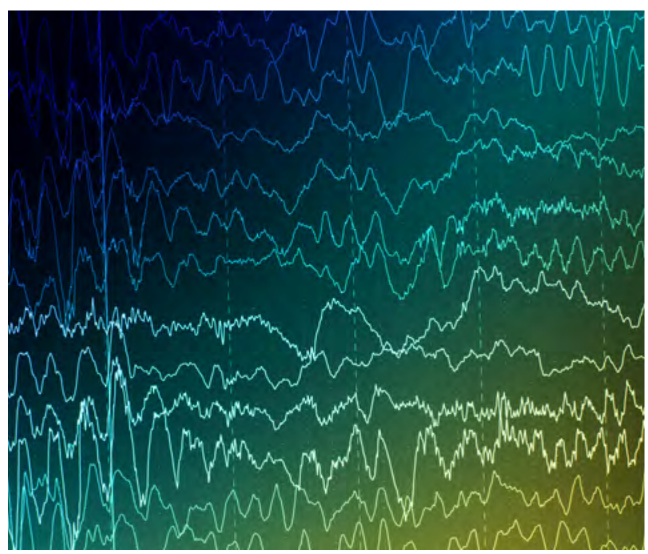
In Europe, the GDPR is the applicable framework to any processing of personal data for the purposes of scientific research, including where the research relies on special categories of personal data, such as data related to health and biometric data processed for identification. There are several lawful grounds for processing under Article 6(1) that would allow the necessary processing of personal data for BCI research, as well as several permissions under Article 9(2) for the use of sensitive personal data. In some situations, this could allow data controllers to conduct this type of research even without individual consent for the processing of the data,[77] specifically when sensitive data is necessary for public health purposes or for research in the public interest;[78] however, there are many complexities surrounding this sort of processing, with the European Data Protection Board (EDPB) expected to adopt Guidelines on processing of personal data for scientific research purposes in the following months. Given the complexities surrounding human subject research and privacy, health researchers and other stakeholders seeking to develop or adopt BCIs, will need to understand and verify how the product fits into the shifting regulatory landscape.

The EU's recent proposed draft AI regulation[79] covers all AI systems, including those relying on biometric data—and is likely to be relevant for future regulation of personal neurodata, significantly altering the regulatory landscape around BCIs and neurotech. It specifically focuses on AI systems that pose high risks to the "health, safety and fundamental rights" of individuals. BCIs that might be considered "high risk" AI systems under the proposed regulation, could trigger requirements prior to entering the market such as going through a conformity assessment, adoption of adequate risk assessment, security guarantees, and adequate notice to the user, among others.[80] If considered a "low risk" system, organizations would have to fulfil transparency requirements.[81] The full scope and impact of the EU's AI regulation on the development and use of BCIs remains subject to the ongoing legislative process.

B. Gaming BCIs Often Augment Existing Platforms and Controls and Offer Players New Ways to Play Through Recording Neurodata

Gaming is one of the most prominent consumer applications of BCI technology. In turn, advances in gaming may serve as a dry run for innovations in other sectors with a more immediate impact on human wellbeing.

Today, most BCI gaming experiences involve outfitting existing devices and platforms with neurotechnology. Gaming and entertainment-focused BCIs were originally created for people with motor disabilities—and still offer accessible experiences for that community today—but are now increasingly targeted to the broader population.[82] The most common integration of BCI technology in gaming involves the player wearing an external device—often a headband, cap, or plastic arm touching the player's forehead—fitted with a non-invasive neurotechnology, such as EEG. These devices attempt to record the player's electrical impulses, collecting and interpreting the player's brain signals during play.



An example of an EEG recording.[83]

One of the earliest examples of EEGs in gaming is NeuroSky's 2007 game The Adventures of NeuroBoy.[84] With the use of a Bluetooth and EEG-fitted headset, called MindSet, the game claims to measure the player's concentration and stress during play and provide this information to the player.

Through concentration of thought, the player is able to move objects in the game, but NeuroBoy still relies on mouse and keyboard commands for much of the gameplay.[85]

Since the advent of games like The Adventures of NeuroBoy, BCIs in gaming have evolved to where recording neural signals is now a primary driver for gameplay, rather than working in tandem with traditional controls. However, the immersive experiences offered by most of the current applications of BCI gaming remain limited. Generally, players can only complete a discrete set of actions with their thought patterns. Star Wars Force Trainer II comes with a non-invasive EEG wearable, and the game claims that players can use their thoughts, or "the force," to control a levitating holographic image of an x-wing.[86] EEG wearable games like Star Wars Force Trainer II cannot accurately detect when the player is thinking about specific directions such as "up" or "down" but rather assigns these movements to an arbitrary set of brain signal patterns, which inform the player's neural signature.

Games involving BCIs are not limited to single-player experiences, but have applications pointing to a future of multiplayer and social games. Cornell University researchers developed BrainNet, the first multi-person non-invasive brain-to-brain interface (BBI).[87] In BrainNet, three participants, outfitted with external EEG and TMS caps, play a game similar to Tetris.[88] Two of the players can see the entire game screen, while the third can only see the block at the top of the screen. The two players who can see the entire screen "send" neurodata to the third player about how they should rotate the block to complete a row. The third player "receives" the neurodata and then sends a command via nerve impulse to the game, indicating whether or not to rotate the block. While not yet widely available, this type of collaborative gameplay increases the potential for a more interactive BCI gaming experience. Moreover, BBI interfaces could unlock a new method for completing collaborative tasks and communicating outside the realm of gaming.

Other innovations in BCI gaming involve augmenting platforms with BCI technology. This form of augmentation is most common today in the extended reality (XR) gaming space. Extended reality is the umbrella term used to describe augmented reality (AR), virtual reality (VR), and mixed reality (MR) technology.[89] Today, when BCIs are integrated into XR technology, it is typically through the use of a headset called a head-mounted display (HMD). In the BCI context, HMDs are fitted with electrodes which non-invasively collect neurodata needed for gameplay without the use of cumbersome technology or dozens of EEG electrodes.[90] Companies like Neurable are developing their own HMDs outfitted with EEG electrodes and software compatible with other HMDs outfitted with the EEG electrodes.[91] In Neurable's first demo, Awakening, the player assumes the role of a psychokinetically-gifted child who must escape from a government prison.[92] Through recording the player's electrical brain impulses, the BCI HMD lets the player choose between a host of objects to escape from prison and advance through the game.[93]

The future of BCI gaming may provide fully-immersive experiences where the player can initiate a diverse set of in-game actions with their conscious thoughts. Here, the player's neurodata would be collected and combined with other biometric or physiological information derived from their gestures,[94] eye movements,[95] facial expressions,[96] breathing,[97] and heartbeat.[98] OpenBCI[99] is currently developing Galea, a software and hardware platform that uses existing HMDs, most notably the Valve Index. The device collects neurodata along with data from the wearer's heart, skin, muscles, and eyes through a number of sensors with the initial goal of providing developers the tools to explore further integrating this data into future projects.[100]

Other future advances in BCI gaming will prioritize social interaction with other players. Immersive games will continuously record and process neurodata and other physiological data to respond and adjust in real time—or after the fact during a later experience—to a player's expressed mood and skill level.[101] Some game developers predict that immersive gaming BCIs will be able to modulate players' brains to alter moods during gameplay as well as providing "better than real visuals" in games.[102]

1. Gaming BCI Risks Include the Involuntary Collection of Neurodata, Which Could Lead to Granular User Profiles that Result in Decisions Potentially Impacting and Limiting the User Experience

Key privacy risks associated with BCI gaming are less about user identifiability, but rather manifest from the inferences about a user's psychology and preferences and how organizations might make decisions based on these inferences. These risks are especially prevalent when augmenting existing gaming platforms, particularly VR, with BCI and neurotechnology sensors. In VR, data is collected about the immersive digital world in which a user is interacting. When combining a user's real-time neurodata with the content a user is currently experiencing in VR, a profile can be built about an individual in which inferences can be drawn about a user's responses to the virtual content they are being served.

Brittan Heller has coined the term "biometric psychography," which describes the notion of combining collected biometric or biological data with information about the virtual stimuli encountered by the user to produce inferences about the user's psychology.[103] For instance, changes in recorded neurodata throughout a user's play session could lead to conclusions about whether particular content excites, arouses, induces fear, or psychologically impacts a user. Further, when neurodata can be combined with other biological data which produces inferences about a user's psychology, including changes in pupil size, timing and direction of eye gaze, changes in skin temperature, and changes in heartbeat, increasingly detailed profiles reflecting a user's psychological response to content can be inferred.

Unlike other biological indicators, neurodata could provide potentially heightened sensitive details about an individual's psychology collected directly from the brain in real time to gain insight into a user's intent or neurological reactions. In turn, AI and machine learning models can be trained on a user's brain signals—in combination with other biological changes in response to content—allowing organizations to associate user-specific changes in neural signals to certain physiological states, such as arousal. Moreover, changes in brain signals might be even more involuntary than something like eye gaze, which a user has the option of controlling, unlike their electrical neurosignals.

Risks are magnified when decisions that impact the user are influenced by company or third-party deduced neurodata inferences. Decisions could include: which content to serve to a user, which ads a user might view during BCI gaming, and other activities across the Internet based on a user's involuntary brain signal responses. Beyond ads, there are genuine concerns that one's neurodata could be used to expose vulnerabilities that could be exploited by nefarious actors who purposefully target digital spaces that cater to children (e.g., human trafficking).[104]

Today, content recommendations are seen across gaming, streaming, and other online services. Currently, the service of content is based on a voluntary action by the user, such as listening to a particular song or viewing a particular video, visiting a certain website, or "liking" a post on social media. In the case of BCI gaming, content may one day be served based on involuntary neurological responses of the user. Therefore, the types of content—including ads—served to users can be determined not only by their voluntary entertainment consumption, but further determined by involuntary inferences resulting in increasingly granular profiles about individuals. Additionally, content served to users based on increasingly granular profiles including their brain signals could be shared with third parties for advertising or other purposes, further tailoring the experience users have across the Internet—sometimes without user knowledge or consideration of user wishes.

Another concern about inferences resulting from the collection of neurodata is whether or not these inferences are accurate, especially given the nascent and limited utility of non-invasive BCIs today. When the inferences about a user's psychology are especially accurate, providers run the risk of serving content so reflective of a user's interests that it could promote severely addictive gameplay or desensitization to various forms of entertainment or interaction, and other potentially unhealthy habits. When these inferences are inaccurate, providers run the risk of turning off certain users from enjoying content and serving them content and ads that do not comport with, or at times offend, their interests. Whether these inferences are accurate or not, increasingly granular profiles dictating which content to serve, or not serve, a user could result in enhancing the division and filter bubbles found online today. Moreover, if these inaccurate inferences are sold to third parties for non-advertising or non-gaming purposes, there could be opportunities for impermissible discrimination across a wide variety of other domains.

2. Some BCI Gaming Applications are Regulated by Children's Privacy Regulations or General Biometrics Laws

A regulation that could uniquely impact BCI gaming in the United States is the Children's Online Privacy Protection Act (COPPA). Many games, including some of the games described above, are directed to children under the age of 13 and as such the personal information collected is covered by the Children's Online Privacy Protection Act (COPPA).[105] COPPA applies to "operators" of online services directed to children under 13 or those who have actual knowledge that they are collecting, using, or disclosing personal information from children under 13. COPPA provides parents and guardians with a number of rights over their children's personal information, including access to the child's information and deletion rights over the data. The law places a number of requirements on organizations such as posting a clear privacy policy on their website, providing direct notice to parents, obtaining parental consent before collecting information from children under 13, and enacting reasonable security to protect the child's information.

While biometric information, including neurodata, is not explicitly covered under COPPA, children's neurodata, if used to identify a particular child, could be swept into the law as a "persistent identifier," which is covered under COPPA. Additionally, the Federal Trade Commission (FTC) is currently considering amending COPPA to include biometric data.[106] It is yet to be seen whether biometric data will be swept into a new iteration of COPPA, and whether the definition of biometrics would cover neurodata. Regardless of whether neurodata will be specifically covered under COPPA, developers should be aware that BCI games and other toys that connect to the Internet that collect children's other personal information, such as name, address, image, or audio recording could potentially fall under COPPA.

Other potentially applicable laws in this space are certain state biometric laws, which provide a number of rights to individuals over their data and place requirements on companies collecting biometric data, including but not limited to: prohibitions on collecting, processing, using, or sharing biometric information without prior opt-in consent; data security requirements that meet industry standards; and (in the case of the Illinois law) the ability for individuals to bring private rights of action for violation of the law. However, none of these laws explicitly cover neurodata. Some state biometric laws define biometrics narrowly and are less likely to be interpreted to cover neurodata as written today. For instance, the Illinois Biometric Information Privacy Act (BIPA) defines a biometric identifier as being limited to: "a retina or iris scan, fingerprint, voiceprint, or scan of hand or face geometry."[107] Other state biometric laws such as the Washington law (WASH. REV. CODE § 19.35.010) define biometric identifiers more broadly as "data generated by automatic measurements of an individual's biological characteristics, such as a fingerprint, voiceprint, eye retinas, irises, or other unique biological patterns or characteristics that are used to identify a specific individual."[108] State biometric laws with broader definitions of biometric identifiers, like that in Washington state, could cover personal neurodata if it is used as an identifier.

Additionally, comprehensive privacy laws, such as the EU's General Data Protection Regulation (GDPR)[109] and the California Privacy Rights Act (CPRA)[110] could cover personal neurodata with their broader definitions of biometric data. However, current laws that could cover personal neurodata are framed in terms of the ability to identify an individual based on biometric data. Concepts such as "biometric psychography" and accompanying inferences may not be interpreted as covered under these laws.

C. Employment and Training BCIs Can Monitor Employee Engagement During High-Risk Tasks, Report Employee Cognitive Data to Employers, Modulate Employees' Neural Signals to Improve Their Abilities, and Provide New Tools to Efficiently Complete Tasks

One of the most prominent uses of BCIs in the employment and industry context is measuring engagement during high-risk tasks. Engagement-measuring technology is marketed for jobs where attention is crucial for performance and prevention of physical harms, such as those in sports or transportation. One noteworthy engagement-measuring BCI is Life, developed by Smartcap,[111] which features an EEG headband that fits inside hardhats, trucker caps, and other headgear that notifies truckers and employers when they are drowsy or inattentive while driving.[112] Life and similar technologies are intended to combat the estimated 70% of trucking accidents caused by fatigue.[113]

Other engagement-measuring BCIs combine neurodata with other biometrics to measure and encourage employee engagement. AttentivU is a pair of glasses fitted with both EEG electrodes measuring neurodata and sensors for tracking eye movements.[114] The technology combines these data streams to draw conclusions about the wearer's fatigue, engagement, and cognitive load. The device indicates to the wearer when their attention level changes through audio feedback and a connected vibrating scarf.

Other BCIs in the employment context are used to collect information related to workers' moods.[115] In some Chinese factories, state-owned companies, and various transport contexts, workers are required to wear BCI headsets that collect neurodata to measure not only their attention, but also sudden negative mood changes like acute anxiety, rage, or pronounced distress.[116] Similarly, one could imagine a sort of "HR dashboard"[117] in which employee engagement or moods are accessed by management who could use this data for purposes such as gauging efficiency, managing workloads, worker happiness levels, or use this data to make employee hiring, firing, or promotion decisions. Additional research efforts are underway for the development of BCIs as lie detectors.[118] While much of this research is occurring in the law enforcement, government, and military space, these technologies may have implications in the private sector, especially for employees who work on confidential projects.

Modulating BCIs in the employment space are touted as a tool for improving workers' performance and ability to multitask in fast-paced environments through the use of transcranial direct current stimulation (tDCS), developed by companies such as Caputron.[119] tDCS involves a headset fitted with electrodes inside sponge inserts that conduct electricity from the wearer's scalp.[120] While the use of tDCS is not yet widespread in the employment context, some early tests show that the technology could enhance multi-tasking efficiency by approximately 30%.[121]

Some forecasts suggest BCIs will be used for job training by requiring invasive BCI technologies, which are directly installed into the user's brain.[122] Elon Musk's Neuralink company promotes the aspirational goal of installing "neural lace," consisting of many tiny electrodes, into the brain.[123] A tissue-like lace overlay that drapes over parts of an individual's brain would have numerous advantages over devices that only pick up signals in certain regions. Such an overlay could yield a more fulsome representation of the wearer's thoughts. Further, invasive implants could avoid some of the safety pitfalls of non-invasive devices that have the potential to break blood vessels or injure tissues. However, invasive implants necessarily involve surgery, which comes with its own set of risks. One of Musk's goals is to make Neuralink users, whether they use the neural lace technologies or another variety of BCI, "smarter" by improving memory and aiding decision-making, crucial during a high-pressure or time-sensitive task. While these innovations appear far from fruition, Neuralink is currently testing neural lace technology on animals, and is planning to conduct its first human tests in 2021.[124] Additionally, early work has shown that certain BCIs might enhance episodic memory—the ability to recall and reexperience memories from the past.[125]

Other non-invasive neurotechnologies show promise in enhancing employee abilities. Companies like Facebook are looking to integrate non-invasive EMG wristbands into emerging technologies, such as virtual or augmented reality, which can collect a user's motor neurons to capture a user's intent to move their fingers or other appendages.[126]

Additionally, researchers developed an invasive BCI that allows users to type by thinking about writing specific letters.[127] While this technology is far from mass market—and given its invasive nature might be best suited to provide accessibility to patients with paralysis—such technological breakthroughs could have widespread impact on the employment landscape. This could result in users performing tasks such as typing with their minds at a faster rate than the dexterity of their hands would typically allow. Such devices might one day change how workers send emails, code programs, or communicate with colleagues.

1. Employment BCI Risks Include: Eroding Worker Privacy While Chilling Behavior, Making Impactful Decisions About an Employee Based on Inaccurate Science, A Lack of Employee Control Over Their Neurodata, Workers Questioning Their Identity; and More

BCIs that monitor employee engagement during high-risk activities might effectively promote safety and save lives. However, such technologies could compromise employee privacy and autonomy. An employee who is knowingly being monitored might increasingly distrust their employer, lose morale, or chill their behavior—including union organizing.[128] On the other hand, some might view the collection of a limited neurodata set for safety purposes as less privacy-invasive[129] than other technologies like in-vehicle cameras.[130] However, even if the collection and analysis of neurodata is less privacy-intrusive (a claim very much up for debate), employees might have equal or greater feelings of being surveilled given the nascence, opacity, and complexity of a technology recording data from their brain.

Privacy questions also emerge around whether the employee, employer, both, or neither ultimately should have control over employee neurodata. This is further complicated when an employer institutes a bring your own device (BYOD) policy, in which case the employee might own their own device, but the employer might have control—in full or in part—of the employee's associated neurodata.

Comprehensive privacy laws, such as the CPRA, provide a number of rights to individuals as consumers over their personal data—such as the right to access, correct, delete, or export their personal information—but do not currently extend these same rights to employees. However, the CPRA will be extending its protections to employees beginning in 2023. A lack of employee control over their data could further erode employee trust, reduce autonomy, and open the door for recorded neurodata to be used for purposes unrelated to their employment, such as building advertising profiles. Their data might also be used for purposes which could inadvertently violate worker privacy involving health data (e.g. influence insurance coverage) or litigation (e.g. workman's compensation).

Relatedly, many risks stem from the ability—or lack thereof—of employees to consent, or not, to being monitored or having their brains modulated. Even in situations where employers will only monitor or modulate employees' neurodata upon obtaining express consent, inherent power imbalances between employers and employees create a dynamic where employees could be less willing to refuse to consent, or opt out, of monitoring for fear of retaliation, losing out on a promotion, or reducing chances for a raise. There is also the concern of fairness between employees based on their choice to use the technology or not, since a disparity in information and engagement by employees who opt in vs. those who opt out could make it more difficult to equitably judge performance between workers.

Risks around employee monitoring are further heightened when employers make decisions about employees based on this data. Decisions based on the collection of employee neurodata could include disciplinary measures, hiring and firing decisions, and other potentially adverse actions. Concerns are exacerbated as experts have questioned the accuracy of some emotion detection[131] technology using neurodata or other biometric inputs,[132] meaning that employees could be unjustly punished or inappropriately rewarded, based on inaccurate and unproven science. Additionally, emotion detection is gaining traction in the US in contexts such as job recruitment,[133] which could include the collection and analysis of neurodata in the near future.

Employees who use stimulating BCIs to enhance cognitive and work performance might question their own identity and psychology.[134] Studies have shown that the emotional or behavioral changes in patients might cause them question whether their psychological state is attributable to the BCI or themselves.[135] Workers questioning their identity could reduce or confuse their sense of agency, their capacity to make decisions, and their identity as human beings both in and outside of the workplace.[136]

2. Workplace Monitoring, Collective Bargaining, and Employee Privacy Laws Apply to BCI Use in Some Employment Contexts

Workplace monitoring laws place limitations on some types of BCI-based employee monitoring. The Electronic Communications Privacy Act (ECPA) prevents employers from monitoring employees' personal phone calls but allows them to monitor "workplace communications," especially when those conversations take place on company devices like company-owned computers and telephones.[137] Existing anti-discrimination measures, including the Americans with Disabilities Act (ADA),[138] may restrain employers who would use the results of a BCI that reveals a disability in hiring or firing decisions.

U.S. law grants employers broad leeway in defining workplace privacy policies for at-will employees. By contrast, unionized employees, which comprise roughly 11% of the total American workforce, often stipulate enhanced workplace privacy protections as part of collective bargaining agreements.[139] The types of protections vary depending on the circumstances, but they typically limit the use of workplace monitoring systems known as "management by algorithm," which are new forms of monitoring and surveillance using data generated by workers—potentially including neurodata—that could exacerbate discrimination and systemic inequality.[140] The GDPR recognizes the inherent power imbalances between employee and employer for activities such as employee monitoring by noting that consent can only serve as a lawful basis for processing employee personal data under exceptional circumstances.[141]

The use of BCIs as lie detectors in the employment space remains limited, but there are federal laws that specifically protect employee privacy in a narrow manner. The Employee Polygraph Protection Act protects potential employees (absent some exceptions) from hiring or firing practices on the basis of a lie detector result.[142]

Other regulations of note include state microchip laws, which generally prohibit employers or organizations from requiring employees to be implanted with microchips.[143] Today employers are not requiring or offering that employees install invasive BCIs or other neurotech into their brains, but there are non-neurotech examples of employees who have the option of being "chipped" by employers.[144] Organizations engaged in employee tracking should be cognizant of these microchip laws and should consider how a future, invasive BCI would be covered under these legal regimes.

D. BCIs in Education Record Neurodata to Help Inform Individualized Learning Models and Provide Real-Time Feedback to Students and Teachers on Student Engagement and Progress

Proponents of BCIs in education argue that BCIs can help students in both K-12 and higher education learn, retain information, pay attention, increase empathy, and improve academic achievement.[145] Recent developments in educational BCIs are cited as helping optimize students' workload and curriculum difficulty in response to individual needs.[146] It is widely recognized that learning is optimized when educational materials map to a student's cognitive strengths.[147] Digital learning environments implementing BCI technology would gather neurodata from students using EEG, and estimate the difficulty of workload based on a student's brainwaves.[148] The tools can then adapt the difficulty of assignments in real time to maximize learning. One of the celebrated elements of customized learning occurs when the material meets the "Goldilocks test," which measures task achievement as neither too easy nor too difficult, but just right.[149]

Addressing a different aspect of learning, some education technology companies are developing BCIs that measure students' classroom attention levels. For example, BrainCo, Inc. is developing BCI technology that involves students wearing EEG-fitted headbands in class.[150] The students' neurodata is gathered and displayed on a teacher's dashboard which is said to provide insight into student attention levels. Student metrics may also be shared with students' parents, keeping them up-to-date on their children's performance in class.[151]

1. Educational BCI Risks Include: Making Decisions About Students' Cognitive Abilities Based on Inaccurate Inferences, Chilling Student Speech, and Perpetuating Injustice

A major risk in the education field arises from inaccurate or incomplete neurodata used to make inferences about students' cognitive abilities.[152] In many ways these concerns mirror those found in the employment space. Measuring a student's brain signals to gauge attention levels or ability to grasp certain material using inaccurate and not well-understood data, and then using this information for making important decisions about a student's engagement, achievement level, or academic potential could result in miscategorizing a student as either a strong or struggling student.

Neurodata can be unreliable or inaccurate for a number of reasons such as: poorly fitting devices; devices not containing enough sensors; sullying the quality of a dataset from facial or body movements; or faulty, not well understood, and not well tested underlying science. This could put students at risk for incorrect penalties for inattentiveness or other perceived behaviors. Further, requiring students to wear EEG headsets might "chill" a student's speech (or thoughts) if they feel they are being surveilled, as previous studies on the effects of being monitored have shown. Moreover, feelings of being surveilled could reduce student and parent trust in the school and the educational system as a whole.

This chilling of speech could be doubly true for students with a perceived history of acting out in school, students who are particularly vulnerable, have learning differences such as ADHD,[153] struggle with mental health, or come from communities heavily surveilled by law enforcement or others. This could be especially true when BCIs are used exclusively or disproportionately among certain subgroups of students or in disciplinary settings, such as detention.[154] The Health Advanced Research Projects Agency (HARPA),[155] has looked into surveilling students' social media activity. This sort of school safety measure in combination with neurodata could lead to further limiting students' need to appropriately "vent" online, or drawing inaccurate conclusions related to the content posted online by students. While educational BCIs are sometimes touted as leveling the playing field for students, disproportionate use of BCIs, or BCIs used among certain groups of students could increase rather than relieve injustice. Moreover, the tracking of student's cognitive processes and taking action based on this tracking could lead to further stigmatization of learning differences or mental health concerns.[156]

2. Federal, State, and Local Student Data Laws Typically Place Requirements on Schools and Neurotech Companies Collecting, Using, and Sharing Personal Neurodata, While Granting Rights to Students and Parents

While BCIs may introduce unprecedented collection and sharing of neurodata in the education context, there are dozens of privacy regulations that touch on education privacy at the local, federal, and international level. Currently, all 50 states and Washington, DC have introduced student privacy legislation, each with its own requirements.[157] Not all of this legislation would have bearing on BCIs, however, schools, teachers, and BCI companies should be cognizant of the applicable laws and provisions in each state where the technology is used. In addition, stakeholders should be aware of school and district-specific policies and best practices governing student data as well as the concerns of parents and school boards. Developers and purveyors of BCI technologies should proactively and transparently communicate their practices to engage and empower parents and community leaders.

At the federal level, there are a variety of privacy regulations that specifically impact education. One of the most relevant is the Family Educational Rights and Privacy Act (FERPA),[158] which protects education records at all schools that receive federal funding.[159] Education records contain information directly related to an individual student and are maintained by an educational agency or institution or by a party acting for the agency or institution. In certain contexts, a student's personal neurodata could be part of an education record falling under the protection of FERPA—which includes biometric records.[160] Parents and guardians hold a number of rights over their children's data (students themselves hold these rights when over the age of 17), while restrictions are placed on school officials maintaining education records.[161] For example, school officials might not be permitted to disclose personal neurodata collected from students to third parties without express consent from parents and guardians.

E. Research Efforts are Underway for Integrating BCIs Into Smart Cities and Communities for Enhanced Communication for Construction and Public Safety and for New Methods of Control for Connected Vehicles

One of the more future-facing sectors for BCIs is the smart cities and smart communities[162] space where researchers look to integrate BCIs into smart vehicles and urban planning and construction design. In the US today, technological mapping of public and private spaces is becoming ubiquitous, and a number of emerging technologies have already entered the smart city arena.[163] For example, sensors and other technologies are increasingly integrated in: transportation including smart cars and bike share services; utilities including smart power grids and smart water meters; telecommunications including public broadband; government services including gunshot detectors and parking monitoring; and environmental monitoring including smart trash cans and environmental sensors.[164] In the future, neurotechnologies could serve as another set of sensors—in this case collecting neurodata—for aiding city and transportation efficiency, public safety, and energy monitoring.

BCI research is increasingly focused on integration into smart cities and communities for enhanced communication promoting efficiency and safety. For example, Neurable[165] and Trimble,[166] recently announced that they are utilizing BCIs alongside technologies like GPS to provide training and safety services for the transportation, architecture, engineering, and construction industries.[167] Such technologies could provide voice-free and hands-free communication interaction between construction workers and engineers, while also providing analytics for tracking training efficiency and worker and citizen safety.[168] Firefighters, paramedics, and other public protection workers could benefit from this technology, and could operate as members of an integrated team if able to directly collaborate with one another via BCI.[169] One could imagine firefighters operating in conjunction, and with greater safety, if they could communicate in real time without the need for a voice interface, or in the case of voice and other communication outages. Similar research into BCIs as communication devices is prevalent in the military context with projects such as Silent Talk, allowing soldiers to communicate via neural signals without the need for verbal speech.[170]

Other BCI research focuses on transportation. As early as 2014, researchers proposed a prototype for a Bluetooth-enabled BCI that could control a smart car.[171] Research and prototypes involving BCIs for connected vehicles is still in the early phases.[172] But as the connected vehicle landscape expands, BCIs and other neurotechnology could be increasingly integrated into connected vehicles for purposes such as vehicle control or monitoring drivers' attention levels behind the wheel. Recent innovations include Hyundai's Mr. Brain project, which is designed to measure a driver's attention through collecting brainwaves using an earpiece sensor.[173] The device can be connected to a companion smartphone app that notifies the driver when they are losing their concentration.[174]

Moreover, research into BCI-controlled drones is currently underway.[175] The ability to control smart cars, drones, or other vehicles could promote accessibility to those who lack the motor functions to control vehicles today and could promote safety by monitoring driver fatigue levels and warning drivers when they are drowsy behind the wheel.

1. Privacy Risks of BCIs in the Smart Cities and Communities Space Include Increased Surveillance, Public Safety Concerns, and Exacerbating the Digital Divide

Near-term BCI innovations in smart cities will likely augment existing sensors, potentially heightening existing privacy concerns in the smart cities context. A major flashpoint in the privacy debate today relates to both public and private surveillance of communities, especially those that have been historically surveilled and over policed. Advocates have pinpointed technologies such as facial recognition, license plate readers, cell site simulators, and drones as more privacy invasive than traditional surveillance technologies such as cameras or wiretaps with the power to locate a vehicle, device, or person among a crowd of many with the potential to gather associated metadata, personal information, or content of communications. Privacy risks are magnified when these technologies are deployed in historically surveilled communities by reducing individual privacy rights, chilling speech, eroding public trust, and perpetuating systemic inequalities related to race, social status, gender, national origin, and other sensitive attributes. Integrating neurotechnology sensors into community architecture, vehicles, and the public square could lead to the collection, storage, and sharing of neurodata by law enforcement for surveillance purposes. Combining neurodata with other personal information could lead to even more invasive surveillance than individuals are currently experiencing.

Other concerns emerge around public safety. Early prototypes of vehicles controlled fully, or in part, by an individual's brain signals cannot be operated with the same precision as vehicles controlled with steering wheels, controllers, or other haptics. It is unlikely that vehicles controlled solely by the mind will enter the market in the near future, but new public safety questions will emerge around vehicles controlled by BCIs.

Concerns related to the exacerbated digital inequity could also be prevalent in the smart cities space. Communities that are already more connected and have adopted smart city technology will be more likely to have the infrastructure in place and resources available to implement BCIs in public. On the other hand, communities that lack these same technological investments are less likely to be early adopters and could fall further behind, only increasing the digital divide at national (wealthy vs. low-income neighborhoods and communities) and international (global north vs. global south) levels.

2. BCIs in Smart Cities Are Starting to be Governed[176] by a Mix of Legal Frameworks

While companies developing smart cities technology are responsible for complying with privacy, security, and other related regulations, ultimately it is often up to local governments to regulate emerging technology integrated into modern, connected communities. Local laws, ordinances, and frameworks contain their own idiosyncrasies, often vary between localities, cities, and states, and sometimes are written to align with the particular values of their communities. However, it is important to recognize that local ordinances and regulations are sometimes subject to preemption by state or federal regulation. On the international level, laws governing smart cities technology could contain vast differences, often highly dependent on differing cultures and government systems. For example, cultures that place a greater emphasis on individual freedom might codify individual rights and obligations on emerging technologies differently than communities that place a greater emphasis on collective wellbeing. Smart city infrastructure and associated emerging governance are already complicated at the baseline, and the potential integration of BCIs into this space will only make technical and regulatory considerations more complex. As such, it remains to be seen how the BCI smart city landscape will unfold and what the ultimate privacy implications will be.

F. Neuromarketing Involves Recording Neurodata to Gain Insight Into Individuals' Reactions, Preferences, and Motivations When Encountering a Product or Service

Neuromarketing generally refers to collecting physiological and neural signals for the purposes of learning about individuals' reactions, mood, preferences, and motivations when purchasing or using a product or service.[177] Neuromarketers typically use two brain scanning methods—functional magnetic resonance imaging (fMRI) and EEG.[178] fMRI offers researchers deeper and potentially more accurate insights into how consumers make decisions based on various stimuli than the more accessible and less expensive EEG methods.[179] In one well-publicized study using fMRI scanning, participants were asked to drink unlabeled soft drinks.[180] Absent brand cues, participants displayed little preference for either Coca-Cola or Pepsi; however, when given brand cues around which beverage they were drinking, participants displayed heightened brain activity in areas correlated with recall and memory.[181] These tests revealed positive feelings like nostalgia when it came to the participant's preferred drink.[182] Understanding why individuals choose the products and services that they do poses untold benefits for advertisers.[183] Where fMRI is too inaccessible or expensive, neuromarketers turn to less accurate, but more accessible, portable, and less expensive EEG methods.[184]

Often in tandem with fMRI or EEG technology, neuromarketing researchers gather information from sources other than direct neural signals. Alternative tracking methods include: eye tracking, pupil dilation, skin conductivity, and facial expression coding as a way to quantify attention, arousal, and psychology. When neurodata is combined with these other inputs, the advertising profiles tied to individuals will become increasingly granular and more attractive to advertisers, third parties, and other stakeholders in the advertising technology ecosystem looking to share, sell, and place more impactful behavioral ads to these individuals across the Internet.

1. Neuromarketing Risks Include the Repurposing of Personal Neurodata for Advertising, Promoting Addicting or Unhealthy Behaviors, and Inadequate Consent When Collecting or Sharing Involuntary Neurodata Due to Poor Transparency

The adoption of BCIs across numerous sectors could pose unprecedented privacy risks within the ad tech ecosystem. While granular user profiles for advertising purposes exist today, adding neurodata would further animate already detailed profiles, revealing more details about a particular individual and inferences about their preferences. Many BCIs across various sectors, by their very nature, collect personal neurodata. Organizations collecting and retaining personal neurodata—and other related information—for various purposes could be incentivized by advertiser dollars to share or sell this data for advertising.

Further, the use of neurotechnologies in marketing could provide stakeholders insight into new and sensitive inferences about an individual's sexual preferences, arousal, health, and other especially sensitive details. Not only could this offend individuals' notions of privacy, and erode user trust, but could incentivize the further collection of especially sensitive information encouraging the creation of increasingly granular, and sensitive, profiles sought after by advertisers for delivering more impactful behavioral ads. If taken too far, granular and accurate profiles could lead to serving advertising content which encourages addictive activities related to content consumption, gameplay, gambling, or promoting unhealthy habits. Granular profiles built from inaccurate biometric data collection can also lead to inaccurate conclusions about individuals and can falsely target advertising content to them.

Additionally, the privacy risks and associated consequences could extend well beyond frustration or annoyance when advertising profiles are shared or sold to third parties for purposes other than advertising. One could imagine a scenario where impactful decisions could be made about individuals based on advertising profiles, such as health care premiums determined in part by a users' preferences for a "healthy" or "unhealthy" diet based on both buying decisions and how their neurons react to certain food.

Moreover, mood and eye tracking software—as it exists today—can collect involuntary responses of a user in reaction to stimuli. Involuntary responses could be especially valuable to advertisers because they could reveal unfiltered user preferences ripe for impactful behavioral advertising. The tracking of involuntary responses makes user transparency and control especially difficult because it is often happening without user awareness. The current widespread model of companies' terms of service and privacy policies stating information such as: "we will be collecting data from this device and software to understand more about you," would well miss the mark of providing transparency to users. Organizations engaged in tracking involuntary brain signals and other biometric or physiological measurements from users might rethink current consent protocols, as well as transparency and explainability models, for providing both an accurate and clearly understood snapshot of what data is being collected from users and for what purposes.

2. Neuromarketing is Potentially Governed by Comprehensive Privacy Laws, FTC Enforcement Authority, and Neuromarketing-Specific Codes of Ethics

State laws such as the CPRA provide a number of rights to consumers, including rights of access, information, deletion, portability, and right to opt out of "selling" personal information, while placing new obligations on businesses. Personal neurodata is not specifically mentioned in the law, but such information could be classified as "biometric information"—covered and broadly defined under CPRA. The CPRA offers a specific opt out of "cross contextual behavioral advertising" (aka advertising targeted to an individual based on their behavior online).

In addition to comprehensive privacy laws, the Federal Trade Commission (FTC) has authority to investigate, under Section 6 of the FTC Act, and authority to enforce penalties on the basis of deceptive and unfair trade practices—including those related to advertising—under Section 5 of the Act.[185]

Other than laws and agency enforcement, voluntary self-regulatory initiatives could also inform this space. The Neuromarketing Science & Business Association's (NMSBA's) Code of Ethics enshrines commitments around integrity; consent (including requiring informed consent from parents when studies involve children); transparency; and privacy.[186] These ethics codes could act as tools to educate and guide organizations wading into this emerging and unique sector of advertising. Additionally, the United Nations Convention on Rights of the Child has called for the specific prohibition of certain forms of advertising to children, including neuromarketing, signaling that some policymakers view neuromarketing as creating heightened risks for vulnerable populations, such as children.[187]

G. Military BCIs include Restorative Devices, Communications Tools, Vehicle and Weapon Control, Deception Detection, and More

Today, military use of BCIs is largely non-invasive and focused on the creation of restorative devices for injured service members.[188] However, the U.S. and China have explored the viability of BCIs as next-generation weaponry. In the U.S., Defense Advanced Research Projects Agency (DARPA) recently announced $104 million in funding to support its Next-Generation Nonsurgical Neurotechnology (N3) program, which provides funding for researchers to develop high-performance brain-computer interfaces for military service members.[189] These devices are intended to be non-invasive, allowing "super-warriors" to control drones and other vehicles with their brain signals during complex military operations.[190] Other military research includes BCIs for communication between military personnel, such as Silent Talk, in which personnel communicate via neural signals without the need for verbal speech or gestures.[191]

Much of the research in the military space is informed by breakthroughs from other sectors. Notably, DARPA recently awarded a number of grants to BCI researchers,[192] including a project from the University at Buffalo in which neurodata is collected from videogamers during gameplay in hopes of using this data to train future advanced AI robots for military use.[193] The military has expanded its research into deception detection using BCIs, taking a page from law enforcement and other defense offices' use of polygraph research.[194]

Innovations in invasive BCIs in the civilian arena adopted for military use could lead to massive breakthroughs with implications for both modern warfare and society at large. For instance, DARPA's Restoring Active Memory (RAM) program aims to help with memory recall and formation for service members suffering brain injury through the use of an invasive BCI.[195] RAM involves similar technology and methods as invasive BCIs that have proved effective for stroke, Alzheimer's, and head injury patients.[196]

1. Risks Associated with Military BCIs Include Hacking, Reduction in Battlefield Teamwork, and Physical and Mental Harm

Use of BCIs on the battlefield leads to risks such as disruption of service or interception of signals by adversaries.[197] Like other technologies deployed by the government and military, BCIs could become the latest system that could be compromised by hackers. BCIs that collect and record brain signals could open the door for enemies to gain access to communications, strategy, and secrets. More troubling is the possibility of hackers gaining control over modulating BCIs and physically and mentally harming military personnel.

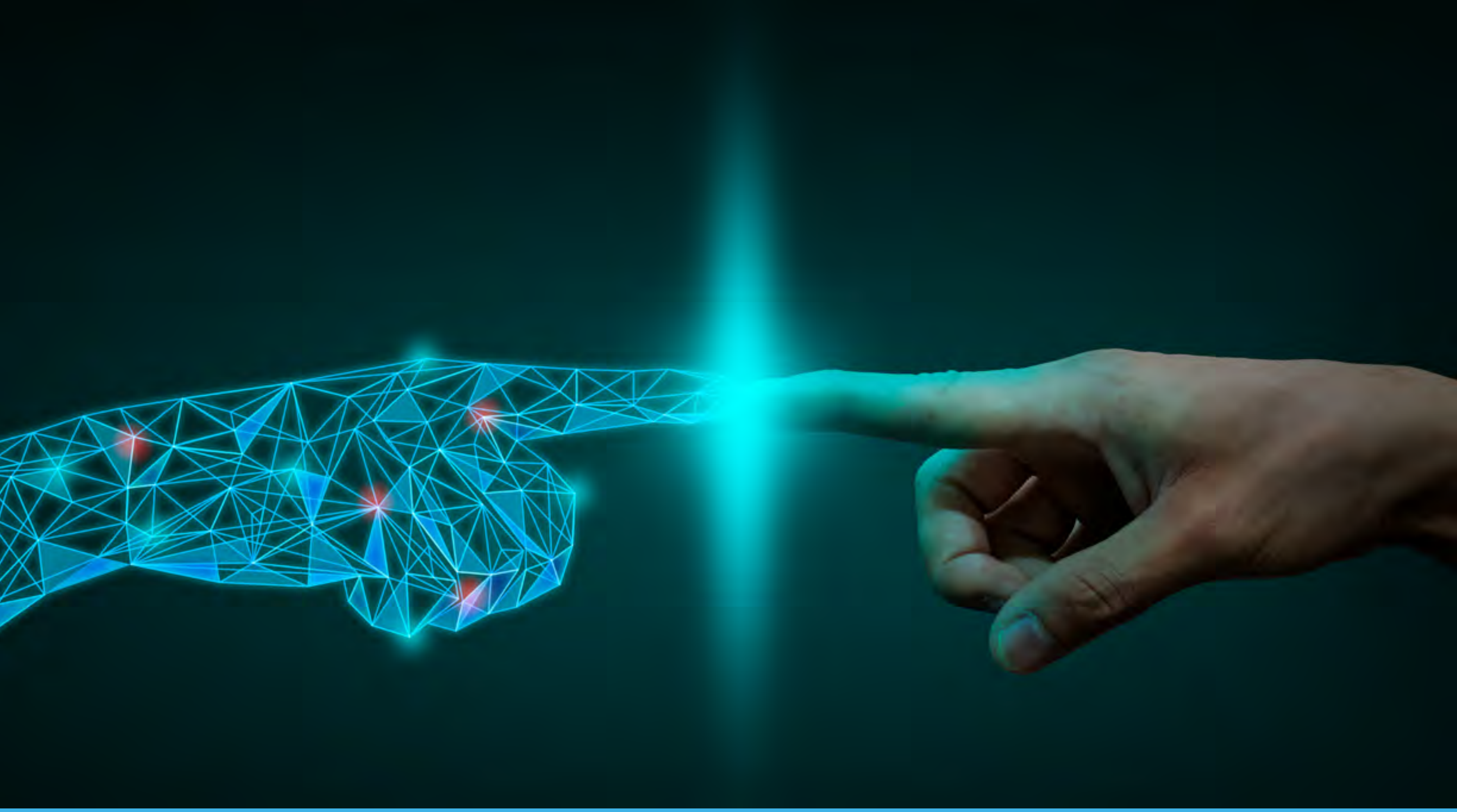
Additional risks relate to an erosion of teamwork and comradery between soldiers on the battlefield and in training when using BCIs for communication.[198] While it is possible that communication between soldiers using BCIs could increase bonding and trust, encouraging soldiers connecting to one another through a new and currently limited technology could also erode cohesion, comradery, and a group dynamic important for encouraging cooperation between military personnel.

Other concerns are more future-facing. While BCIs are not currently being deployed for torture or pacification, developers in his space would be wise to consider the ethical implications of using BCIs for these purposes. Controversy and ethical concerns around the military's use of torture have existed for decades, and BCIs could offer another avenue for a military organization to engage in these activities. Additionally, weapons that target neurodata and nervous systems may proliferate, such as uncharacterized directional phenomena in the form of vibration, pressure, and sound such as those experienced by U.S. military personnel in Havana, Cuba.[199] Time will tell whether BCIs are used for these purposes and whether they will be more or less humane than current methods.

2. Some Military Use of BCIs is Governed by Military Ethics, International Treaties, and U.S. Constitutional Law

While BCIs in the military are still nascent, there are existing military ethics guidelines[200]—and international treaties such as the Geneva Convention[201]—that could prohibit future use of invasive BCIs on subjects without consent.[202] However, it is important to note that to our knowledge, today there are no military regulations limiting the use of non-invasive transcranial stimulation in particular for torture, pacification, or interrogation.[203]

Military BCIs might also be governed by U.S. constitutional law depending on their use. BCIs used for purposes such as deception detection could violate the Fifth Amendment's "guarantee against self-incrimination" because collecting a soldier's thoughts might not constitute a permissible physical piece of evidence.[204] Moreover, BCIs used for this purpose could run up against the Fourth Amendment as an unreasonable search and seizure.[205] However, others argue that Fourth and Fifth Amendment protections might not apply to neurodata collected by BCIs because of a history of real-time collection of medical data being admissible as evidence in the court of law and the third-party-doctrine resulting in users forfeiting their expectation of privacy over data shared with a company.[206] Various international treaties might also govern BCIs used for interrogation. If it is determined that a BCI is used in conjunction with a "toxic chemical"—defined as a chemical that can cause "temporary incapacitation"—this could be in violation of the Chemical Weapons Convention (CWC).[207]



Part III: A Mix of Technical and Policy Solutions Can Mitigate Risks

Responsible use of BCIs and associated neurodata is paramount in the health and wellness area, as well as the consumer and military contexts. A diverse and inclusive list of international stakeholders spanning end-users, directly and indirectly impacted communities, interested or invested industries and marketplaces, academia, and governments, and others must commit to articulate a vision for how technology, law, and policy can shape these services in a way that is beneficial to all with sufficient privacy protections. The challenges in meeting this goal are significant.

While BCIs have shown demonstrable benefits for healthcare for a number of years, the technology—especially in the consumer market—is in its infancy. With a scant number of exceptions—most notably BBI technology—breakthroughs in health services have informed BCI use in the consumer market. Open questions emerge around how moving this technology into the consumer space evolves the privacy and ethical risks seen today in the health context. Moreover, because the uses of this technology are often especially future-facing—even as compared to other emerging technologies—there is no way to comprehensively and accurately predict the specific risks that will emerge in the decades to come. Allowing these technologies to evolve absent strong accountability and enforcement frameworks will result in substantial risks. The guidelines, frameworks, and regulations cited throughout this work—including GDPR, CPRA, OECD Guidelines, and the proposed EU AI framework—could serve as a foundation for future rules governing BCIs. But regulation must be cognizant of the need to provide a structure for future technological advances and uses, as well as new risks. Moreover, in addition to laws, the proposition that existing human rights conceptualizations need to be updated to reflect these concerns is gaining momentum in some neuroscience spaces—this is an idea around which further discussion is warranted (see the call-out box below on neurorights). The grand challenge of promoting strong privacy protections for BCIs will require a mix of technical and non-technical solutions. While not comprehensive or definitive, the following suggestions provide a starting point.

Case Study: Neurorights in Chile

On October 25, 2021, the Chilean government approved a constitutional reform[208] to protect "the mental integrity of neurotechnologies."[209]

Chile is also considering a neuroprotection bill,[210] based on five fundamental human rights-based principles: the right to personal identity, free will, mental privacy, equitable access to technologies that augment human capacities, and the right to protection against bias and discrimination.[211] The bill would likely limit the use of neurotechnologies and associated neurodata to clinical and health research and therapy, meaning that many of the consumer-focused use cases described in this report would likely be prohibited. The bill also provides a number of noteworthy rights and requirements including: obtaining express, opt-in consent from the user when engaging with neurotechnology; providing notice of possible physical, cognitive, or emotional effects of the treatment; retaining neurodata for only the time necessary to carry out the purpose for which the neurodata was collected; and requiring the state to promote equitable access of neurotechnologies in the public interest.

Perhaps most noteworthy, the bill calls for the collection, storage, treatment, and dissemination of neurodata to be treated as an organ under Chilean organ transplant law.[212] This treatment of data as an organ could create practical consequences, while significantly limiting both medical and non-medical use of neurotechnologies and neurodata including: prohibiting the selling of personal neurodata to neuromarketers and researchers; prohibiting the collection of neurodata from patients 18-years-old and younger; and prohibiting patients from receiving neurotechnology-related treatment who do not have full use of their mental faculties and do not have a positive physical fitness report.

Philosopher Abel Wajnerman Paz argues that analogizing neurodata with organ transplants is not a logical fit because neurodata, unlike an organ, contains no organic material, is produced by others outside human bodies, and requires "elaborate construction by clinicians and researchers."[213] Dr. Paz provides an alternative avenue for regulating neurotechnologies suggesting instead regulating neurodata as intellectual property. Dr. Paz argues that this could enable the data subject to financially benefit from sharing their neurodata and may lead to creating large data repositories needed for Parkinson's and Alzheimer's research.[214]

A. Technical Solutions Include: Providing On/Off and App Controls to Users; End-to-End Encryption of Neurodata, Privacy Enhancing Technologies, and More

1. Developers Should Provide On/Off Controls Where Possible and Provide Granular Controls on BCI Devices and Companion Apps

The notion of on/off controls for tracking technologies as a form of privacy protection is not new; however, the need for some BCIs to be "always on," or on for extended periods, especially in the health context, complicates the debate around such devices. In the consumer context, an "always on" default is typically not essential for the device to function properly. In these cases users should have a clear and definite way to control when BCIs are on or off with a hard on/off switch on the device, or through on/off controls readily accessible through a companion app. As with other devices, there are considerable privacy risks when a BCI is always gathering data or when it can be turned on unintentionally, collecting data without the user's knowledge.[215] These risks are magnified when BCIs record personal neurodata that could be combined with other information overtime to draw vast and sensitive inferences about the personal lives of users.

In addition to on/off controls, BCI companies developing and deploying BCIs should provide granular controls to users for managing their neurodata, and other associated personal information. Many consumer BCI devices rely on companion mobile apps, which should provide user controls. While companies and device manufacturers ultimately have the best understanding and expertise regarding what data is necessary to operate BCIs, user controls are crucial safeguards to ensure that individuals can manage data collection, deletion, use, and sharing.

2. Developers Should Utilize Best Practices for Privacy and Security to Store and Process Neurodata and Use Privacy Enhancing Technologies Where Appropriate

Regardless of whether neurodata is stored and processed on a BCI device, by a companion app, or on a server operated by the BCI provider, developers should seek to maximize privacy and security. Developers should rely on storage and computing services that can meet appropriate security standards commensurate with the sensitivity of the neurodata. Developers should also look to privacy enhancing technologies as a way of maximizing the utility of neurodata, while minimizing privacy risks. Techniques could include differential privacy, in accordance with principles of data minimization and privacy by design. When appropriate, they should use de-identification methods like Privacy Preserving Data Mining (PPDM) and Privacy Preserving Data Publishing (PPDP) for stored and shared data.[216] Additionally, developers should ensure sensitive personal neurodata is encrypted when in transit and at rest. These techniques could be especially useful in the BCI space, as the neurodata collected by BCIs could be ripe for data driven research in the medical field. These techniques are often promoted as a way to maximize the utility of data for research, while minimizing user identifiability.

Researchers should also stay abreast and implement appropriate security safeguards. Poor cybersecurity can leave systems vulnerable to hacking, data breaches, and other malicious activities, endangering user safety. Device hacking is especially dangerous as many BCIs are used for critical health management regimens. Not only could a bad actor access personal neurodata and other collected personal information, but more alarmingly control how a device modulates, or fails to modulate, a patient's brain, resulting in physical or psychological harm. Given how quickly the technology, capabilities, and threats in this space are evolving, cybersecurity professionals should take time to consider appropriate, practical, and tailored solutions. A good starting place could be the National Institute of Standards and Technology (NIST) Cybersecurity Framework—a dynamic resource consisting of standards, guidelines, and best practices built to adapt to a particular technology, use case, and context.[217]

B. Policy Solutions Include: Rethinking Transparency and Control; IRBs and Ethical Review Boards; Multi-Stakeholder Engagement; and Standards Setting and Other Agreements.

1. Given the Novelty of BCIs, Along with the Complexity of Recording and Modulating Neurodata, Organizations should Rethink Traditional Transparency and Control Models

The novelty and complexity of BCIs warrants an emphasis on transparency and control beyond most other emerging technologies. Transparency and control frameworks might have to be rethought in the neurotechnology field. Consumer, government, and health-focused BCIs can vary significantly in their technological capabilities, sophistication, machine learning techniques, purposes, and user-bases, often presenting differing privacy risks. These differences often warrant different levels and methods of transparency necessary for consumers, patients, and lawmakers to understand device capabilities, data flows, data storage, and who controls and has access to the data, while encouraging informed consent. For example, a non-invasive EEG-based device that only records neurodata along with an individual's eye movements, muscle movements, and heartbeat—does not have the same risks as a health device that records and modulates a patient's brain using an invasive BCI. Despite these significant differences, BCIs as a whole are often incorrectly framed and lumped together by the popular media as "mind reading technologies from the future" that can capture and understand the innermost thoughts and workings of the human mind.

Developers and regulators should think creatively about how to promote the transparency necessary for meaningful user control. Privacy policies, terms of service, and other similar documents, while required by law, are often not effective means of providing transparency on their own. Even when these privacy policies are accurate in describing consumer rights and data governance, they might still lack transparency in that they are difficult to understand, vague, and fail to show the complete picture of what is happening with consumer data. In the absence of strong enforcement and without a commitment to trust, transparency, and explainability, privacy policies are likely neither agile enough to keep pace with quickly evolving technology nor adequately accessible to end-users.

Furthermore, although there are attempts to make user controls more flexible, more research is needed on how to best enable user control in ways that are more fluid, nuanced, and longitudinal. BCIs that operate in conjunction with companion apps could provide pop-up notice with the option for users to access more detailed information in a layered approach before consenting to device recording or modulating or other terms. BCI developers might want to also consider using audio and visual cues understandable to users, indicating when a device is recording or modulating. In the future, developers might take advantage of this particular technology by sending a particular signal to a user's brain indicating some sort of activity. In this scenario, the user can respond to this signal with a particular thought pattern providing or denying consent.

2. When Appropriate, BCI Providers Should Engage IRBs or Independent Review Boards, as well as Multi-Stakeholder Engagement Before and During Roll Out of New BCI Products or Services

In some circumstances, BCI providers might be required to complete IRB review before gathering primary research data from human subjects or pre-registering clinical trials. Organizations may need to obtain proper approval from bodies like the FDA prior to rolling out new BCI products and services. However, BCIs in the consumer market are not typically subject to these same requirements. One option for consumer-focused BCI organizations seeking to promote strong privacy protections would be committing to an independent review board to consider questions around neurodata collection, use, sharing, storage, and other related concerns. A number of prominent AI researchers and developers have crafted principles and approaches to AI and ML.[218] Because BCIs often involve the use of AI and ML, many of these AI principles will inform BCI development. However, AI frameworks do not contemplate all of the major challenges around recording or modulating a user's brain. As BCIs become more widespread, providers should consider creating internal BCI-specific principles for informing their internal design, policy, and technical decisions. Review boards could also determine whether BCI-related data should be used for research where obtaining prior user consent is impractical.

Organizations should also facilitate multi-stakeholder engagement throughout the development and deployment lifecycle of BCIs. Stakeholder outreach should include researchers, policy professionals, early adopters of the technology, and those who either have yet to adopt the technology but might do so in the future or may be impacted due to the use of technology by others. The latter group should include those who are often not given a seat at the table when developers make ethical decisions about emerging technology. This should include individuals from vulnerable populations, such as the disability community, individuals from historically surveilled communities, and individuals from geolocations most exposed to digital inequity, among others. The conversation with all stakeholders, and perhaps most crucially with vulnerable populations, should be co-participatory and co-created from the start, meaning that providers should not only inform these populations about the technology, but absorb community feedback and integrate this feedback into internal decision making. Providers should be sure to present these changes and their internal design and decision-making process back to these stakeholders to help continue facilitating an ongoing and collaborative conversation. Further, providers should be engaging these stakeholders from the start of product development, research, and rollout. Providers should avoid premature decisions prior to community engagement, and should be willing to change course, heavily alter, or altogether scrap a project if it runs counter to a particular communities' preferences or could foreseeably cause harm.

3. Companies, Research Institutions, and Policymakers Should Set Policy and Technical Standards for BCI Research, Development, and Use that are Capable of Adapting as the Technology, User Base, and Uses Evolve

Because of the fast-moving nature of this technology, industry, research institutions, and policymakers should draft and subscribe to standards, best practices, and pragmatic regulations. As indicated in this report, a number of laws, best practices, and enforcement bodies can serve as foundations for neurotechnology-specific standards and frameworks. If and where possible, technical and governance communities should leverage existing policies, practices, and bodies pertaining to related technologies to govern BCIs, as well as identify places where existing frameworks or processes do not sufficiently address novel risks.

The latter point is particularly pertinent, since a number of notable privacy challenges are not addressed by current rules. Many of the existing comprehensive, and sectoral, privacy laws, including GDPR, BIPA, and CPRA, carve out de-identified data. Yet there is still no legal consensus on which types of neurodata can or will be interpreted as biometric data, and in the event that it is, research has shown that biometric data is more difficult to effectively de-identify.[219] Another major gap in current regulation relates to what immersive technology expert Brittan Heller refers to as "biometric psychography," which describes combining collected biometric data with information about stimuli encountered by the user to produce inferences about the user's likes, dislikes, sexual attraction, fears, and other psychology.[220] It might be necessary to rethink and broaden concepts and associated definitions of biometrics to be more inclusive—and therefore more predictive of—downstream emerging properties of neurodata, including psychographical characteristics.

To protect against privacy and responsible governance risks related to these and other BCI-related challenges, stakeholders should develop technical and policy standards for responsible development and use of BCIs capable of adapting as the technology, user base, and use evolves. Technical standards should promote privacy protective techniques, including privacy enhancing technologies; data quality thresholds; testing standards to ensure that AI and ML techniques are accurate, interpretable, and explainable; among several other elements. Policy standards should include standards related to privacy by design, user profiling, purpose limitations, data minimization, contractual agreements between BCI manufacturers and third parties related to de-identification, data sharing, and retention, among other concerns.

Alongside technical and policy standards, industry and regulators should promote up-to-date training for developers around processes such as data handling and de-identification learned from academia. For example, depending on the magnet strength, some fMRI images are capable of reconstructing an individual's face.[221] It is common practice in the academic neuroimaging sector to remove the first few slices or images of a file before uploading to a database to prevent identification through 3D reconstruction of a participant's face. But this is not common practice across all organizations who collect or share these kinds of images, particularly in open-source communities. In addition, stakeholders should consider a policy-driven call to action for the development of tech-driven safeguards to test for these kinds of errors and flag them, remove them, or fix them.

4. BCI Stakeholders Should Encourage the Adoption of Open Standards for Neurodata and Share De-Identified Research Data Under Open Licenses to Promote an Open and Inclusive Research Ecosystem

The development of neurotechnologies presents significant barriers to entry, as BCIs often require significant capital investment and highly specialized skill sets that would likely be inaccessible to all but a select few of companies and organizations. This creates an environment in which leading neurotechnology organizations could create proprietary standards, fragmenting the neurotechnology research ecosystem. This would prevent many in industry and academia from: accessing the best and most cost-effective tools available, sharing their knowledge, and incorporating diverse perspectives to advance innovation in the field. To minimize such barriers to an open and inclusive research ecosystem, companies and other stakeholders should support the development and widespread adoption of open standards for neurodata. Stakeholders may also consider whether open-licensing of properly de-identified and consented neurotechnology and neurodata research datasets is feasible and appropriate—while this has the potential to maximize data accessibility by trusted researchers.

5. Policymakers Should Review the Adequacy of Existing Policy Frameworks for Governing the Unique Risks of Neurotechnologies

As established by this report, neurotechnologies can pose both familiar and novel risks. For familiar risks, such as vulnerability to hacking, the need to protect sensitive data, or the collection of data from minors, existing policy frameworks likely apply just as effectively to neurotechnologies as they do to consumer and medical technologies available today. However, the unique risks posed by neurotechnologies, such as the potential erosion of mental privacy or even more challenging concerns such as the implications for free will and human agency, highlight the possibility that existing policy frameworks may be insufficient to adequately protect people from harm. Furthermore, as neurotechnologies mature and become more commonplace, new applications unimaginable today will pose a host of new, unforeseen risks and benefits that today's policy frameworks were not designed to address.

Policymakers and other BCI stakeholders should carefully evaluate how existing policy frameworks apply to neurotechnologies and identify potential areas where existing laws and regulations may be insufficient for the unique risks of neurotechnologies. Importantly, policymakers should prioritize a focus on well-defined risks, while tracking developments that can raise future concerns. Future advances may create unexpected problems, but may also be mitigated by other factors in the future such as yet-to-be-developed technological safeguards or changing societal norms. Potential decisions to ban particular high-risk uses of neurotechnology should similarly be discussed and considered in depth among experts prior to such decisions. Regardless, it is critical that policymakers are well educated about the risks neurotechnologies can pose and potential solutions to these risks so that they can swiftly and effectively implement these solutions when appropriate.

CONCLUSION

As BCIs evolve and are more commercially available across numerous sectors, it is paramount to understand the unique risks such technologies pose. It is just as important to understand how these technologies work and what data is necessary for them to function. Privacy and data governance risks can be minimized through broad adoption of both technical and policy recommendations that can make BCI data less identifiable, less potentially harmful, and more secure. Because the field of neurotechnology is especially future-facing, developers, researchers, and policymakers will have to create best practices and policies that consider existing risks and strategically prioritize future risks in ways that balance the need for proactive solutions while mitigating misinformation and hype; deciding which of the technical, social, or policy issues outlined in this report to prioritize first remains an open but vitally important area for discussion and concrete action. BCIs will also likely augment and be combined with many existing technologies that are currently on the market. This means that new technical and ethical issues are likely to arise and existing issues could be compounded with one another. In the near future, BCI providers, neuroscience and neuroethics experts, policymakers, and societal stakeholders will need to come together to consider what constitutes high-risk use in the field and make informed decisions around whether certain BCI applications should be prohibited, a position around which more robust and critical discussion is needed. Finally and perhaps more fundamentally, it is also possible that the future of privacy itself and our notions of what it means to have or obtain privacy at basic human or societal levels could be challenged in ways that we cannot currently comprehend or anticipate. We hope this report and our ongoing work helps support the technical, legal, and policy developments that will be required to ensure the advances in this sector are implemented in ways that benefit society.

ENDNOTES

1. Concepts such as mental privacy, human agency, and fairness are complicated, contextually-dependent, and culturally-influenced. Likewise, terms used throughout this report—such as conscious, unconscious, subconscious, or intentional—have diverging meanings for neuro-scholars, legal experts, and the general public. We do not have the space in this report to dive deeper into these notions; however, it is important to acknowledge their nuance up-front, and we recommend that conversations around these topics and efforts at better standardizing the language used in this space is warranted and should be prioritized.
2. Although the definition of neurodata is the same for humans and animals, the focus of this report is neurodata coming from human nervous systems. There are also two points worth mentioning for the sake of clarity. First, while the majority of neurodata is currently related to neurons (their electrical, hemodynamic, and chemical activity, their anatomical components, their connections, etc.), there already exists neurotechnology which targets glia—helper cells of the nervous system—to change perception and health. While this report is focused on neuronal neurodata, It is widely believed that these sorts of non-neuronal applications will continue to grow in the future, and thus what is included in the concept of neurodata is likely to expand and change in parallel. Second and related, it is a scientific fact that any human behavior can be traced back to neurodata; for the purposes of this report, we constrain the focus to primary neurodata and first order proxies of neurodata, but it is important to acknowledge that second-order or downstream behaviors and associated analyses of these behavioral data may also be seen as extensions of neurodata by some neuroscientists, neurotechnicians, and neuroethicists in the field.
3. While often connected to the Internet, some BCIs, including those that rely on implantable pulse generator technology (IPG) use radiofrequency, rather than internet technologies such as WiFi or Bluetooth for communication and control.
4. *See* Andrea M. Matwyshyn, *The Internet of Bodies*, 61 Wm. & Mary L. Rev. 77 (2019), *available at* https://scholarship.law.wm.edu/wmlr/vol61/iss1/3/.
5. *See* Marcello Ienca & Gianclaudio Malgieri, *Mental Data Protection and the GDPR*, 4 (May 5, 2021), *available at* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3840403, coining the term: "digital mind" to describe the "moment-by-moment quantification of the individual-level human mind using data from neural interfaces and other digital technology—and a more intimate connection between minds and machines."
6. The Institute of Electrical and Electronics Engineers, Inc., *Standards Roadmap: Neurotechnologies for Machine Interfacing*, (2020), https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/presentations/ieee-neurotech-for-bmi-standards-roadmap.pdf.
7. There is no currently agreed-upon definition of technological maturity within the neurotech community or a mappable timeline to reasonably expect translation of neuroscience research into direct-to-consumer products. Therefore, concepts such as "near-term" or "far-term" are not well delineated and may change depending on the marketplace. Moreover, given that there are multiple technologies emerging or evolving simultaneously, it is unknown what (if anything) will change and propel the field forward faster than imaging. This is particularly true where technologies intersect (e.g. artificial intelligence + neurotech or quantum computing + neurotech). While it is necessary to dampen hype and misinformation around the field as this can create unrealistic expectations or unwarranted fears, it would be unwise to not plan for more advanced capabilities whenever, or if ever, they arise. Research on predicting the trajectory of BCI's and other neurotechnological capabilities would be particularly useful for aiding in planning and prioritizing issues while still remaining vigilant towards potential future or unknown down-stream consequences.
8. Bidirectional BCIs are systems that translate neural signals recorded from various areas of the brain into certain actions or sensations and perceptions (for example, using motor cortex signals to create motor commands). In addition to bi-directional BCIs, BCIs can also be closed loop—meaning that the device senses the effect of the modulation and then alters this modulation based on the observed effect. Closed loop BCIs are often used to treat movement disorders like Parkinson's Disease or sensorimotor impairments caused by spinal cord injury. *See* Patrick D. Ganzer et al., *Restoring the Sense of Touch Using a Sensorimotor Demultiplexing Neural Interface*, Cell (Apr. 23, 2020), *available at* https://www.cell.com/cell/fulltext/S0092-8674(20)30347-0.
9. Simon Little et al., *Adaptive Deep Brain Stimulation in Advanced Parkinson Disease*, Annals of Neurology (Jul. 12, 2013), *available at* https://onlinelibrary.wiley.com/doi/full/10.1002/ana.23951; S. Andrew Josephson, *A Novel Brain-Computer Interface Approach to Deep Brain Stimulation for Parkinson's Disease* (2013), https://www.medscape.com/viewarticle/814726.
10. *See* SLUCare, *After Sudden Hearing Loss, Cochlear Implant Returns Patient's Quality of Life*, (Sept. 24, 2019), https://www.youtube.com/watch?v=Mb0wlYsq_UM; *see also* Ann Perreau, et al., *Programming a Cochlear Implant for Tinnitus Suppression*, Journal of the American Academy of Audiology (Apr. 31, 2020), *available at* https://www.thieme-connect.de/products/ejournals/abstract/10.3766/jaaa.18086.
11. James Wu & Rajesh P. N. Rao, *Melding Mind and Machine: How Close Are We?*, Smithsonian Magazine (Apr. 11, 2017), https://www.smithsonianmag.com/innovation/melding-mind-and-machine-how-close-are-we-180962857/.
12. *Intro to Brain Computer Interface*, NeurotechEDU, (last accessed Jun. 17, 2021), http://learn.neurotechedu.com/introtobci/. There is widely accepted definition of an invasive procedure, but researchers recently proposed a new definition, which defines an "invasive procedure" as one where purposeful/deliberate access to the body is gained via an inclusion, percutaneous puncture, where instrumentation is used in addition to the puncture needle, or instrumentation *via* a natural orifice. *See* Sian Cousins et al., *What Is an Invasive Procedure? A Definition to Inform Study Design, Evidence Synthesis, and Research Tracking*, BMJ Open (Jul. 9, 2019), https://bmjopen.bmj.com/content/bmjopen/9/7/e028576.full.pdf.
13. Jeremiah D. Wander & Rajesh P. N. Rao, *Brain-Computer Interfaces: A Powerful Tool for Scientific Inquiry*, Current Opinion in Neurobiology (2014) 25: 70–75.
14. *See* Angela Chen, *Elon Musk's Dreams of Merging AI and Brains Are Likely to Remain Just That--for at Least a Decade*, The Verge (Apr. 21, 2017), https://www.theverge.com/2017/4/21/15370376/elon-musk-neuralink-brain-computer-ai-implant-neuroscience.
15. *Intro to Brain Computer Interface*, *supra* note 12.
16. Jane Wakefiled, *Elon Musk's Neuralink 'Shows Monkey Playing Pong with Mind'*, BBC (Apr. 9, 2021), https://www.bbc.com/news/technology-56688812; *See* Neuralink, *Monkey MindPong*, YouTube (Apr. 8, 2021), https://www.youtube.com/watch?v=rsCul1sp4hQ.
17. John Koetsier, *Elon Musk Wants to Put a 'Fitbit In Your Skull' to Summon Your Tesla*, Forbes (Aug. 28, 2020), https://www.forbes.com/sites/johnkoetsier/2020/08/28/elon-musk-wants-to-put-a-fitbit-in-your-skull-to-summon-your-tesla/?sh=6b74efb3586a; In addition to Neuralink, several other companies are active in BCI development. *See* Cathy Hackl, *Meet the 10 Companies Working On Reading Your Thoughts (And Even Those of Your Pets)*, Forbes (Jun. 21, 2020), https://www.forbes.com/sites/cathyhackl/2020/06/21/meet-10-companies-working-on-reading-your-thoughts-and-even-those-of-your-pets/?sh=23ed1f26427c.
18. Bryn Farnsworth, *What is EEG (Electroencephalography) and How Does it Work?*, iMotions Blog (Jul. 15, 2019), https://imotions.com/blog/what-is-eeg/.
19. *See* Murta Kulich, et al., Neurosensory Disorders in Mild Traumatic Brain Injury, 23-47, (Michael E. Hoffer & Carey D. Balaban ed., 2019).

20. See Noman Naseer & Keum-Shik Hong, fNIRS-Based Brain-Computer Interfaces: A Review, 9:3 (Front Hum Neurosci) (2015), available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4309034/.
21. *What is Transcranial Direct Current Stimulation?*, Neuromodec, (last accessed May 16, 2021), https://neuromodec.com/what-is-transcranial-direct-current-stimulation-tdcs/.
22. *What is Transcranial Magnetic Stimulation (TMS)?*, Neuromodec, (last accessed May 16, 2021), https://neuromodec.com/what-is-transcranial-magnetic-stimulation-tms/.
23. See Nicola Riccardo Polizzotto et al., Is It Possible to Improve Working Memory with Prefrontal tDCS? Bridging Currents to Working Memory Models, Front. Psycholo. (May 26, 2020), available at https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00939/full; Can Brain Stimulation Aid Memory and Brain Health?, Harvard Health Publishing (Aug. 6, 2015), https://www.health.harvard.edu/mind-and-mood/can-brain-stimulation-aid-memory-and-brain-health, recognizing that more research is needed on the efficacy of brain stimulation for memory retention and learning improvement.
24. Other methods used for non-invasive techniques to study the brain include: positron emission tomography (PET); functional magnetic resonance imaging (fMRI); magnetic resonance tomography (MRT); magnetoencephalography (MEG); among many others.
25. Jerry J. Shih et al., *Brain-Computer Interfaces in Medicine*, 87(3) Mayo Clin Proc. 268-279 (Dec. 8, 2011), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3497935/.
26. *See* Adi Robertson, *I Tried the Wristband that Lets You Control Computers with Your Brain*, The Verge (Jun. 6, 2018), https://www.theverge.com/2018/6/6/17433516/ctrl-labs-brain-computer-interface-armband-hands-on-preview.
27. *Electromyography (EMG)*, Brigham Health (last accessed May 16, 2021), https://www.brighamandwomens.org/neurology/neuromuscular-diseases/electromyography.
28. *Inside Facebook Reality Labs: The Next Era of Human-Computer Interaction*, Tech@Facebook (Mar. 9, 2021), https://tech.fb.com/inside-facebook-reality-labs-the-next-era-of-human-computer-interaction/.
29. This timeline is not intended to be a comprehensive list of neurotechnology breakthroughs, but rather a chronology of some foundational moments in communication interfaces, BCIs, and related technology. While the BCI field is still emerging and innovating, this timeline shows that research related to BCIs is part of a tradition of research related to electronic communication techniques and has been in the works for decades.
30. For more information about identifying individuals based on neurodata, *see* Russell A. Poldrack et al., *Long-Term Neural and Physiological Phenotyping of a Single Human*, Nature Communications (Dec. 9, 2015), https://www.nature.com/articles/ncomms9885; Elise Hu, *< Move Objects with Your Mind? We're Getting There, With the Help of an Armband*, NPR (Jul. 16, 2019), https://www.npr.org/transcripts/717487081.
31. *See* Jason da Silva Castanheira et al., *Brief Segments of Neurophysiological Activity Enable Individual Differentiation*, Nature Communications 12: 5713 (2021), *available at* https://www.nature.com/articles/s41467-021-25895-8.pdf.
32. *See e.g.* Voices of VR, Podcast: #987: The Neuroscience of Neuromotor Interfaces + Privacy Implications with Facebook Reality Labs' Thomas Reardon (Mar. 30, 2021), *available at* https://voicesofvr.com/987-the-neuroscience-of-neuromotor-interfaces-privacy-implications-with-facebook-reality-labs-thomas-reardon-2/, suggesting that while identification based solely on an individual's motor map is not being done today, it is feasible given the uniqueness of motor maps.
33. Emily Gera, *The Neuroscience of Mind-Control Gaming*, Variety (Nov. 26, 2018), https://variety.com/2018/gaming/features/brain-computer-interface-neurable-1203036143/.
34. *Road Transport*, SmartCap (last accessed May 16, 2021), http://www.smartcaptech.com/industries/transport/.
35. Brent J. Lance et al., *Brain-Computer Interface Technologies in the Coming Decades*, 100 Proceedings of the IEEE 1585-1599 (Mar. 1, 2012), *available at* https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6162941.
36. A brain implant has been developed that uses AI to recognize brain activity related to speech and translate the activity into sentences. *See* Jason Arunn Murugesu, *Mind-Reading AI Turns Thoughts Into Words Using Brain Implant*, New Scientist (Mar. 30, 2020), https://www.newscientist.com/article/2238946-mind-reading-ai-turns-thoughts-into-words-using-a-brain-implant/; Facebook hopes to someday incorporate similar technology into VR headsets, which, unlike brain implants, are non-invasive. *See* Daphne Leprince-Ringuet, *Facebook's Mind-Reading Plans Just Took Another Step Forward*, ZDNet (Apr. 1, 2020), https://www.zdnet.com/article/facebooks-mind-reading-plans-just-took-another-step-forward/.
37. Alexandre Gonfalonieri, *Consumer Brain-Computer Interface: Challenges & Opportunities*, Medium (May 18, 2021), https://alexandregonfalonieri.medium.com/consumer-brain-computer-interface-challenges-opportunities-e8204190d828.
38. *Id*., citing Mariam Hassib & Stefan Schneegass, *Brain Computer Interfaces for Mobile Interaction: Opportunities and Challenges*, MobileHCI'15, August 24-27, *available at* https://www.medien.ifi.lmu.de/pubdb/publications/pub/hassib2015mobilehci/hassib2015mobilehci.pdf.
39. *Intro to Brain Computer Interface*, *supra* note 12.
40. IBM defines machine learning as "a branch of artificial intelligence and computer science which uses data and algorithms to imitate the way humans learn, gradually improving its accuracy," IBM Cloud Education, Machine Learning (Jul. 15, 2020), https://www.ibm.com/cloud/learn/machine-learning.
41. We recognize that the neuroscience research sector is already and will continue to be greatly impacted by these kinds of neurotechnologies, as more accessible BCIs will change who can perform what research and at what scale. For example, the company Kernal is making EEGs more affordable and offering neuroscience studies as a service; see Ashlee Vance, Can a $110 Million Helmet Unlock the Secrets of the Mind?, Bloomberg Businessweek (Jun. 16, 2021), https://www.bloomberg.com/news/features/2021-06-16/braintree-founder-s-helmet-size-hospital-aims-to-mine-mind-data. However, the focus in this report is primarily commercial or private sectors, and thus we have excluded basic research as a section in this report.
42. *See* Ellen Wright Clayton et al., *The Law of Genetic Privacy: Applications, Implications, and Limitations*, Journal of Law and the Biosciences, (Oct. 2019) 6(1), *available at* https://academic.oup.com/jlb/article/6/1/1/5489401.
43. *See* Biometric Information Privacy Act (BIPA), 740 ILCS 14/1 (2008), *available at* https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=3004&ChapterID=57; *see also* California Privacy Rights Act (CPRA) of 2020 (2020), *available at* https://www.caprivacy.org/annotated-cpra-text-with-ccpa-changes/
44. OECD Recommendation on Responsible Innovation in Neurotechnology (Dec. 11, 2019), *available at* https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm.
45. Implanted Brain-Computer Interface (BCI) Devices for Patients with Paralysis or Amputation - Non-Clinical Testing and Clinical Considerations, FDA (May 2021), *available at* https://www.fda.gov/regulatory-information/search-fda-guidance-documents/implanted-brain-computer-interface-bci-devices-patients-paralysis-or-amputation-non-clinical-testing.

46. Notably, Article 8 of the European Convention on Human Rights; Articles 7 and 8 of the EU Charter of Fundamental Rights. Many Constitutions in Latin American countries also recognize the right to respect for private life and confidentiality, and sometimes an individual, separate right to protection of personal data. *See also* below our Case Study on Chile and specific neurorights elevated recently at constitutional level.
47. The concept of "personality rights" is generally used to denote the bundle of rights aimed at the protection of the integrity and inviolability of the individual, and it usually encompasses the right to private life, to one's own image, to respect of a person's name, to the inviolability of a person's body, to reputation etc. *See* Giorgio Resta *The new frontier of personality rights and the problem of commodification: European and comparative perspectives* (2011), Tulane European and Civil Law Forum, Vol. 26, p. 33–65.
48. Proposal for a Regulation Laying Down Harmonised Rules on Artificial Intelligence, European Commission (Apr. 2021), *available at* https://digital-strategy.ec.europa.eu/en/library/proposal-regulation-laying-down-harmonised-rules-artificial-intelligence.
49. CPRA, *supra* note 43.
50. General Data Protection Regulation (EU) 2016/679, (2016), *available at* https://gdpr-info.eu/.
51. *See* e.g. Karen S. Rommelfanger et al., *Neuroethics Questions to Guide Ethical Research in the International Brain Initiatives*, 100: 19-36 Neuron (Oct. 2018), *available at* https://www.sciencedirect.com/science/article/pii/S0896627318308237.
52. *See* Xiaotong Fu, et al., *EEG-Based Brain-Computer Interfaces (BCIs): A Survey of Recent Studies on Signal Sensing Technologies and Computational Intelligence Approaches and Their Applications*, IEEE/ACM Transactions on Computational Biology and Bioinformatics (Dec. 2020), *available at* https://www.researchgate.net/publication/347966443_EEG-based_Brain-Computer_Interfaces_BCIs_A_Survey_of_Recent_Studies_on_Signal_Sensing_Technologies_and_Computational_Intelligence_Approaches_and_their_Applications.
53. Emilia Mikołajewski & Dariusz Mikołajewski, *Non-invasive EEG-based Brain-computer Interfaces in Patients With Disorders of Consciousness*, Military Medical Research (2014) 1(14), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4459059/.
54. Masaki Nakanishi et al., *Detecting Glaucoma with a Portable Brain-Computer Interface for Objective Assessment of Visual Function Loss*, JAMA Ophthalmology (2017), 135(6): 550-557, *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5772598/.
55. L. Huang & G. van Luijtelaar, *Brain Computer Interface for Epilepsy Treatment*, IntechOpen (Jun. 5, 2013), *available at* https://www.semanticscholar.org/paper/Brain-Computer-Interface-for-Epilepsy-Treatment-Huang-Luijtelaar/8bdb7cc1897ce0b109d14b61567635b567f681cf.
56. Russ Juskalian, *A New Implant for Blind People Jacks Directly Into the Brain*, MIT Technology Review (Feb. 6, 2020), https://www.technologyreview.com/s/615148/a-new-implant-for-blind-people-jacks-directly-into-the-brain/.
57. *See e.g.*, Frost & Sullivan, *Brain-Computer Interface Hold a Promising Future*, Alliance of Advanced Biomedical Engineering (2017), https://aabme.asme.org/posts/brain-computer-interface-the-most-investigated-areas-in-health-care-hold-a-promising-future.
58. Duncan Graham-Rowe, *Wheelchair Makes the Most of Brain Control*, MIT Technology Review (Sept. 13, 2010), https://www.technologyreview.com/s/420756/wheelchair-makes-the-most-of-brain-control/.
59. *The Brain Powered Wheelchair*, Enabled.in (2014), https://enabled.in/wp/brain-powered-wheelchair/.
60. *Brian Implants Enable Man to Simultaneously Control Two Prosthetic Limbs with 'Thoughts'*, Neuroscience News (Dec. 12, 2020), https://neurosciencenews.com/bci-prosthetic-limb-movement-17423/.
61. *Id*.
62. *See* Mathis Fluery et al., *A Survey on the Use of Haptic Feedback for Brain-Computer Interfaces and Neurofeedback*, Front. in Neurosci. (Jun. 23, 2020), *available at* https://www.frontiersin.org/articles/10.3389/fnins.2020.00528/full.
63. *See* Xiang Zhang et al, *Internet of Things Meets Brain-Computer Interface: A Unified Deep Learning Framework for Enabling Human-Thing Cognitive Interactivity*, IEEE Internet of Things Journal, 6:2, 2084-2092 (Oct 2018), *available at* https://ieeexplore.ieee.org/document/8506382; *see e.g.* Neal Ungerleider, *This Life-Changing Philips Hue Hack Makes the Internet of Everything Mean Something*, Fast Company (Aug. 6, 2014), https://www.fastcompany.com/3034044/this-life-changing-philips-hue-hack-makes-the-internet-of-everything-mean-something.
64. *See* Iris Coates McCall et al., *Owning Ethical Innovation: Claims about Commercial Wearable Brain Technologies*, Neuron (Mar. 2019), 102(4) 728-731, *available at* https://www.cell.com/neuron/fulltext/S0896-6273(19)30289-2.
65. Neurosky Store (last accessed May 16, 2021), https://store.neurosky.com/.
66. *Id*.
67. *Id*.
68. *Id*.
69. *Firmware Update to Address Cybersecurity Vulnerabilities Identified in Abbott's (formerly St. Jude Medical's) Implantable Cardiac Pacemakers: FDA Safety Communication*, iData Research (Jan. 9, 2017), https://idataresearch.com/firmware-update-address-cybersecurity-vulnerabilities-identified-abbotts-formerly-st-jude-medicals-implantable-cardiac-pacemakers-fda-safety-communication/.
70. Ms. Smith, *Hacking Pacemakers, Insulin Pumps and Patients' Vital Signs in Real Time*, CSO (Aug. 12, 2018), https://www.csoonline.com/article/3296633/hacking-pacemakers-insulin-pumps-and-patients-vital-signs-in-real-time.html.
71. Jeffrey Tully et al., *Connected Medical Technology and Cybersecurity Informed Consent: A New Paradigm*, 22(3) J Med Internet Res (2020), *available at* https://www.jmir.org/2020/3/e17612/.
72. Xiao Zhang et al., *Tiny Noise Can Make an EEG-Based Brain-Computer Interface Speller Output Anything*, arxiv (Jul 16, 2020), *available at* https://arxiv.org/abs/2001.11569.
73. Walter Glannon, *Ethical Issues With Brain-Computer Interfaces*, Front. Syst. Neurosci., (Jul. 30, 2014), https://www.frontiersin.org/articles/10.3389/fnsys.2014.00136/full.
74. 45 C.F.R. part 46 (2018), https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=83cd09e1c0f5c6937cd9d7513160fc3f&pitd=20180719&n=pt45.1.46&r=PART&ty=HTML.
75. Connect2HealthFCC - Wireless Health and Medical Devices Background, FCC.gov (last accessed May. 16 2021), https://www.fcc.gov/general/connect2healthfcc-wireless-health-and-medical-devices-background.
76. *See* Muse (last accessed, Oct. 31, 2021), https://choosemuse.com/.
77. The consent usually required for participation in a research project is different and separate than the consent for processing of personal data for the purposes of the research project under the GDPR – *see* EDPB Q&A Document on processing of personal data for scientific health research - https://edpb.europa.eu/sites/...reresearch_final.pdf (February 2021).

78. GDPR, *supra* note 50, arts. 6(1) and 9(2)(i) and 9(2)(j) (2016), *available at* https://gdpr-info.eu/art-6-gdpr/.
79. European Commission, *supra* note 48.
80. *See* Valeria Marcia & Kevin C. Desouza, *The EU Path Towards Regulation on Artificial Intelligence*, Brookings (Apr. 26, 2021), https://www.brookings.edu/blog/techtank/2021/04/26/the-eu-path-towards-regulation-on-artificial-intelligence/.
81. *Id*.
82. Melody Moore Jackson & Rudolph Mappus, "Applications for Brain-Computer Interfaces," in *Brain-Computer Interfaces: Applying our Minds to Human-Computer Interaction*, ed. Desney S. Tan and Anton Nijolt, (2010), London: Springer, 89–104.
83. Raw EEG recordings contain noise and require significant post-processing to provide even rudimentary interpretations. This runs counter to common myths that raw EEG recordings alone can provide deep insight into the inner workings of the human mind and detailed explanations of what the wearer is thinking.
84. Priya Singh, *10 Real Life Examples of BCI Devices That You Can Control With Your Thoughts*, Analytics India Magazine (Nov. 20, 2017), https://analyticsindiamag.com/10-times-companies-made-inexpensive-consumer-based-bci-devices-using-eeg/.
85. Diamond Feit, *Hands On: NeuroBoy, a Game You Play With Your Brain*, Wired (Oct. 1, 2009), https://www.wired.com/2009/10/adventures-of-neuroboy/.
86. *Star Wars Science Force Trainer II Brain-Sensing Hologram Electronic Game,* Amazon.com (last accessed Mar. 16, 2020), https://www.amazon.com/Science-Trainer-Brain-Sensing-Hologram-Electronic/dp/B00X5CCDYQ.
87. Linxing Jiang et al., *BrainNet: A Multi-Person Brain-to-Brain Interface for Direct Collaboration Between Brains*, Scientific Reports (2019), 9: 6115, *available at* https://www.nature.com/articles/s41598-019-41895-7.
88. Sarah McQuate, *How You and Your Friends Can Play a Video Game Together Using Only Your Minds*, UW News (Jul. 1, 2019), https://www.washington.edu/news/2019/07/01/play-a-video-game-using-only-your-mind/.
89. Lauren Goode, *Get Ready to Hear a Lot More about 'XR'*, Wired (Jan. 5, 2019), https://www.wired.com/story/what-is-xr/.
90. Victor Tangermann, *Expert: VR Headsets Should Have Brain Interfaces*, Futurism (Mar. 26, 2019), https://futurism.com/brain-computer-interface-vr-headsets.
91. *See* Neurable (last accessed Mar. 17, 2020), https://www.neurable.com/; Other than EEG electrodes, companies are experimenting with other non-invasive methods, such as fNIRS, integrated into HMDs.
92. Gera, *supra* note 33.
93. *Id*.
94. *See e.g.* Ryota Horie et al., *A Hands-On Game by using a Brain-Computer Interface, and Immersive Head Mounted Display, and a Wearable Gesture Interface*, IEEE Global Conference on Consumer Electronics (GCCE) (2017), https://ieeexplore.ieee.org/document/8229324.
95. *See e.g.* Nataliya Kos'myna, *Project AttentivU*, MIT Media Lab (last updated Feb. 4, 2020), https://www.media.mit.edu/projects/attentivu/overview/.
96. *See e.g.* Seongah Chin & Chung-Yeon *Lee, Personality Trait and Facial Expression Filter-Based Brain-Computer Interface*, International Journal of Advanced Robotic Systems (May 15, 2017), https://journals.sagepub.com/doi/full/10.5772/55665.
97. *See e.g.* Kyle Melnick, *Sundance: Breathe is a Multi-Person Mixed Reality Experience Powered By Breathing*, VRScout (Jan. 24, 2020), https://vrscout.com/news/sundance-breath-multi-person-vr-breathing/.
98. *See e.g.* Neurowear (last accessed Sept. 24, 2021), https://neurowear.com/.
99. *See* OpenBCI (last accessed Feb. 16, 2021), https://openbci.com/.
100. Antony Vitillo, *OpenBCI: Games Using Brain-Interfaces Coming in 3 Years*, The Ghost Howls (Feb. 12, 2021), https://skarredghost.com/2021/02/12/openbci-galea-valve-index-bci/amp/?__twitter_impression=true&s=0.
101. Tangermann, *supra* note 90; another prominent example of BCI technology combined with a VR HMD is the hardware developed by NextMind; *See* NextMind (last accessed Jun. 11, 2021), https://www.next-mind.com/.
102. Luke Appleby, *Gabe Newell Says Brain-Computer Interface Tech Will Allow Video Games Far Beyond What Human 'Meat Peripherals' Can Comprehend*, 1 News (Jan. 24, 2021), https://www.tvnz.co.nz/one-news/new-zealand/gabe-newell-says-brain-computer-interface-tech-allow-video-games-far-beyond-human-meat-peripherals-can-comprehend.
103. Brittan Heller, *Reimagining Reality: Human Rights and Immersive Technology*, Carr Center for Human Rights Policy (Jun. 12, 2020), *available at* https://carrcenter.hks.harvard.edu/files/cchr/files/ccdp_2020-008_brittanheller.pdf.
104. *See* Courtney Fiedman, *Traffickers Targeting People Online More Than Ever Before, Experts Warning Parents*, KSAT.com (Jan. 17, 2021), https://www.ksat.com/news/local/2021/01/18/traffickers-targeting-people-online-more-than-ever-before-experts-warning-parents/.
105. 16 C.F.R. § 312 (1998, updated 2013).
106. Request for Public Comment on the Federal Trade Commission's Implementation of the Children's Online Privacy Protection Rule, 84 FR 35842 (proposed Jul. 25, 2019), https://www.federalregister.gov/documents/2019/07/25/2019-15754/request-for-public-comment-on-the-federal-trade-commissions-implementation-of-the-childrens-online.
107. BIPA, *supra* note 43, 96. 740 ILL. COMP. STAT. ANN. 14/10.
108. WASH. REV. CODE § 19.35.010.
109. GDPR, *supra* note 50, art. 14(4) (2016), *available at* https://gdpr-info.eu/art-14-gdpr/.
110. CPRA, *supra* note 43.
111. *See* SmartCap (last accessed May 17, 2021), http://www.smartcaptech.com/.
112. Julie Weed, *Wearable Tech That Tells Drowsy Truckers It's Time to Pull Over*, New York Times (Feb. 11, 2020), https://www.nytimes.com/2020/02/06/business/drowsy-driving-truckers.html.
113. *Id*.
114. Kos'myna, *supra* note 95.
115. Erin Winick, *With Brain-Scanning Hats, China Signals It Has No Interest in Workers' Privacy*, MIT Technology Review (Apr. 30, 2018), https://www.technologyreview.com/f/611052/with-brain-scanning-hats-china-signals-it-has-no-interest-in-workers-privacy/.
116. Stephen Chen, *'Forget The Facebook Leak': China is Mining Data Directly From Workers' Brains On an Industrial Scale*, South China Morning Post (Apr. 29, 2018), https://www.scmp.com/news/china/society/article/2143899/forget-facebook-leak-china-mining-data-directly-workers-brains.

117. Alexandre Gonfalonieri, *What Brain-Computer Interfaces Could Mean for the Future of Work*, Harvard Business Review (Oct. 6, 2020), https://hbr.org/2020/10/what-brain-computer-interfaces-could-mean-for-the-future-of-work#.
118. *See e.g.* Sujatha K et al., *Brain Computer Interface Technology in Polygraphy*, 117 International Journal of Pure and Applied Mathematics 235 (2017), *available at* https://acadpubl.eu/jsi/2017-117-20-22/articles/22/44.pdf.
119. *See* Caputron (last accessed Jun. 17, 2021), https://caputron.com; *see also Best tDCS Device of 2021*, tDCS.com (Jan. 20, 2021), https://www.tdcs.com/best-tdcs-devices.
120. Royal Society, *iHuman: Blurring Lines Between Mind and Machine*, 42 (Sept. 2019), https://royalsociety.org/-/media/policy/projects/ihuman/report-neural-interfaces.pdf.
121. Justin M. Nelson et al., *The Effects of Transcranial Direct Current Stimulation (tDCS) on Multitasking Performance and Oculometrics*, Military Psychology (2019) 31(3): 212--226, *available at* https://www.tandfonline.com/doi/abs/10.1080/08995605.2019.1598217?journalCode=hmlp20.
122. Gonfalonieri, *supra* note 117.
123. Sarah Marsh, *Neurotechnology, Elon Musk and the Goal of Human Advancement*, The Guardian (Jan. 1, 2018), https://www.theguardian.com/technology/2018/jan/01/elon-musk-neurotechnology-human-enhancement-brain-computer-interfaces.
124. Evelyn Arevalo, *Neuralink Could Start The First Human Trials Later This Year,* Tesmanian Blog (Feb. 8, 2021), https://www.tesmanian.com/blogs/tesmanian-blog/neuralink.
125. John F. Burke et al., *Brain Computer Interface to Enhance Episodic Memory in Human Participants*, Front. Hum. Neurosci. (2014) 8: 1055, https://www.frontiersin.org/articles/10.3389/fnhum.2014.01055/full.
126. Tech@Facebook, *supra* note 28.
127. Francis R. Willett et al., *High-Performance Brain-To-Text Communication Via Handwriting*, 593 Nature, 249-254 (May 12, 2021), https://www.nature.com/articles/s41586-021-03506-2; Pavithra Rajeswaran & Amy L. Osborn, *Neural Interface Translates Thoughts into Type*, Nature (May 12, 2021), https://www.nature.com/articles/d41586-021-00776-8.
128. *See* Gabrielle Rejouis, *Data, Camera, Busted: How Surveillance Interferes with the Right to Organize at Work*, Center on Privacy & Technology at Georgetown Law (May 6, 2020), https://medium.com/center-on-privacy-technology/data-camera-busted-how-surveillance-interferes-with-the-right-to-organize-at-work-ea974763f328, discussing the chilling effects of worker surveillance.
129. Commercial, Smart Cap (last accessed Apr. 11, 2021), http://www.smartcaptech.com/industries/commercial/, arguing that drivers' privacy is protected because the technology does not use privacy-invasive in-cab cameras.
130. *See e.g.* Annie Palmer, *Amazon is Using AI-Equipped Cameras in Delivery Vans and Some Drivers are Concerned About Privacy*, CNBC (Feb. 3, 2021), https://www.cnbc.com/2021/02/03/amazon-using-ai-equipped-cameras-in-delivery-vans.html.
131. *See* Jingxin Liu et al., *Emotion Detection From EEG Recordings*, 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD) (Aug. 13-15, 2016), https://ieeexplore.ieee.org/document/7603437.
132. *See* Hannah Devlin, *AI Systems Claiming to 'Read' Emotions Pose Discriminatory Risks*, The Guardian (Feb. 16, 2020), https://www.theguardian.com/technology/2020/feb/16/ai-systems-claiming-to-read-emotions-pose-discrimination-risks.
133. Patricia Nilsson, *How AI Helps Recruiters Track Jobseekers' Emotions*, Financial Times (Mar. 2, 2018), https://medium.com/financial-times/how-ai-helps-recruiters-track-jobseekers-emotions-3dbd85ffeca0.
134. *See* Gabrice Jotterand & James Giordano, *Transcranial Magnetic Stimulation, Deep Brain Stimulation and Personal Identity: Ethical Questions, and Neurological Approaches for Medical Practice*, 23:5 International Review of Psychiatry 476-485 (2011), *available at* https://www.tandfonline.com/doi/full/10.3109/09540261.2011.616189, specifically discussing identity concerns in the medical context, but these challenges could similarly impact employees using neurotechnology.
135. *See* Eran Klein et al., *Brain-Computer Interface-Based Control of Closed-Loop Brain Stimulation: Attitudes and Ethical Considerations*, 3:3 Brain Computer Interfaces 140-148 (2016), *available a*t https://www.tandfonline.com/doi/full/10.1080/2326263X.2016.1207497.
136. Roberto Portillo-Lara et al., *Mind the Gap: State-of-the-Art Technologies and Applications for EEG-Based Brain-Computer Interfaces*, 5:3 APL Bioengineering (2021), *available at* https://aip.scitation.org/doi/10.1063/5.0047237.
137. Electronic Communications Privacy Act (ECPA), Public Law 99-508, *available at* https://www.govinfo.gov/content/pkg/STATUTE-100/pdf/STATUTE-100-Pg1848.pdf.
138. Americans With Disabilities Act of 1990, Pub. L. No. 101-336, 104 Stat. 328 (1990), *available at* https://www.ada.gov/pubs/ada.htm.
139. U.S. Department of Labor, Bureau of Labor Statistics, *Union Members – 2020* (Jan. 22, 2021), https://www.bls.gov/news.release/pdf/union2.pdf.
140. AFL-CIO, *AFL-CIO Commission on the Future of Work and Unions* (Sept. 13, 2019), https://aflcio.org/reports/afl-cio-commission-future-work-and-unions.
141. GDPR, *supra* note 50, art. 7(4)(i).
142. 29 U.S.C. §§ 2001 – 2009 (2002), *available at* https://www.law.cornell.edu/uscode/text/29/chapter-22, for example EPPA exempts employer use of polygraph exams for certain government employees, defense contract employees, certain employer investigations of employee theft and drug-related conduct, and employees hired to perform security services.
143. *See* Katherine F. Mendez & Christina Jaremus, *Future Employer: Are Humans with Microchips in Their Brains the Future of Work*, Seyfarth (May 19, 2021), https://www.seyfarth.com/news-insights/future-employer-are-humans-with-microchips-in-their-brains-the-future-of-work.html#page=1, citing microchip laws in California, Oklahoma, and Missouri.
144. *See e.g.* Roy Cellan-Jones, *Office Puts Chips Under Staff's Skin*, BBC (Jan. 29, 2015), https://www.bbc.com/news/technology-31042477.
145. *See* Christopher Wegemer, *Brain-Computer Interfaces and Education: the State of Technology and Imperatives for the Future*, International Journal of Learning Technology 14(2): 141 (Jan. 2019), *available at* https://www.researchgate.net/publication/335486095_Brain-computer_interfaces_and_education_the_state_of_technology_and_imperatives_for_the_future.
146. Martin Spüler et al., "Brain-Computer Interfaces for Educational Applications," in *Informational Environments: Effects of Use, Effective Designs*, ed. Jürgen Buder et al., (Oct. 2017), https://www.researchgate.net/publication/320378280_Brain-Computer_Interfaces_for_Educational_Applications.
147. Peter Gerjets & Friedrich Hesse. *When Are Powerful Learning Environments Effective? The Role of Learner Activities and of Students' Conceptions Of Educational Technology*, International Journal of Educational Research (2004) 41(6): 445-465, https://www.sciencedirect.com/science/article/abs/pii/S0883035505000595.
148. Spüler, *supra* note 146.

149. John Sweller et al., *Cognitive Architecture and Instructional Design*, Educational Psychology Review (1998) 10(3): 251--296, https://www.researchgate.net/publication/200772805_Cognitive_Architecture_and_Instructional_Design.

150. Sydney Johnson, *This Company Wants to Gather Student Brainwave Data to Measure 'Engagement'*, EdSurge (Oct. 26, 2017), https://www.edsurge.com/news/2017-10-26-this-company-wants-to-gather-student-brainwave-data-to-measure-engagement.

151. These headbands have since faced backlash for this application: *see* Jane Li, *A "Brain-Reading" Headband for Students is Too Much Even for Chinese Parents*, Quartz (Nov. 5, 2019), https://qz.com/1742279/a-mind-reading-headband-is-facing-backlash-in-china/.

152. Nicole Kobie, *Why Computers Won't Be Reading Your Mind Anytime Soon*, Wired UK (Mar. 12, 2020), https://www.wired.co.uk/article/brain-computer-interfaces.

153. Siobhan Ball, *Glasses Act as a Shock Collar For Students Who Don't Pay Attention*, Daily Dot (Aug. 31, 2019), https://www.dailydot.com/unclick/shock-student-glasses/.

154. Sydney Johnson, Brainwave Headsets Are Making Their Way Into Classrooms—For Meditation and Discipline, EdSurge (Nov. 17, 2017), https://www.edsurge.com/news/2017-11-14-brainwave-headsets-are-making-their-way-into-classrooms-for-meditation-and-discipline.

155. *See* HARPA (last accessed May 17, 2021), https://www.harpa.org/.

156. *See* Jacqueline Alemany, *White House Considers New Project Seeking Links Between Mental Health and Violent Behavior*, Washington Post (Aug. 22, 2019), https://www.washingtonpost.com/politics/2019/08/22/white-house-considers-new-project-seeking-links-between-mental-health-violent-behavior/.

157. *State Student Privacy Laws*, Student Privacy Compass (last accessed May 16, 2021), https://studentprivacycompass.org/state-laws/.

158. 20 U.S.C. § 1232(g) (2001), *available at* https://www.law.cornell.edu/uscode/text/20/1232g.

159. U.S. Department of Education, Family Educational Rights and Privacy Act (FERPA) (last accessed Sept. 25, 2021), https://www2.ed.gov/policy/gen/guid/fpco/ferpa/index.html.

160. U.S. Department of Education, Biometric Record (last accessed May 16, 2021), https://studentprivacy.ed.gov/content/biometric-record.

161. *A Parent's Guide to Student Data Privacy*, ConnectSafely et. al. 3 (2015), https://www.connectsafely.org/wp-content/uploads/2015/04/StudentDataPrivacy.pdf.

162. This report uses the terms "smart cities and smart communities" to refer to communities of all shapes and sizes with digital infrastructure.

163. *See e.g.* Smarter Cities, IBM (last accessed Jun. 17, 2021), https://www.ibm.com/smarterplanet/us/en/smarter_cities/solutions/planning_mgt_solutions/.

164. *See* Shedding Light on Smart City Privacy, FPF (last accessed Jun. 17, 2021), https://fpf.org/uncategorized/smart-cities/.

165. *See* Neurable, *supra* note 91.

166. *See* Trimble (last accessed May 17, 2021), https://www.trimble.com/.

167. *Neurable and Trimble Partner to Explore the Use of Brain-Computer Interfaces For the Transportation and AEC Industries*, Financial Release, Trimble (Jan. 3, 2019), https://investor.trimble.com/news-releases/news-release-details/neurable-and-trimble-partner-explore-use-brain-computer.

168. *Id*.

169. Jiang, *supra* note 87.

170. For more information about Silent Talk, *see* 2010 Defense Department Budget, https://www.darpa.mil/attachments/(2G7)%20Global%20Nav%20-%20About%20Us%20-%20Budget%20-%20Budget%20Entries%20-%20FY2010%20(Approved).pdf; *see also* Patrick Tucker, *It's Now Possible to Telepathically Communicate with a Drone Swarm*, Defense One (Sept. 6, 2018), https://www.defenseone.com/technology/2018/09/its-now-possible-telepathically-communicate-drone-swarm/151068/.

171. Sung-Ja Choi & Byeong-Gwon Kang, *Prototype Design and Implementation of an Automatic Control System Based on a BCI*, Wireless Personal Communications (2014) 79(4): 2551--2563, https://www.researchgate.net/publication/271659937_Prototype_Design_and_Implementation_of_an_Automatic_Control_System_Based_on_a_BCI.

172. *See e g.* Autonomos Labs (last accessed May 17, 2021), https://autonomos.inf.fu-berlin.de/.

173. Paul Myles, *Hyundai Claims Brainwave in Driver Health Monitoring*, Automotive (Jul. 21, 2021), https://www.tu-auto.com/hyundai-claims-brainwave-in-driver-health-monitoring/.

174. *Id*.

175. *See* Andrew London, *I Flew a Drone with My Brain - But That's Only the Beginning*, Techradar (Mar. 24, 2018), https://www.techradar.com/news/i-flew-a-drone-with-my-brain-but-thats-only-the-beginning.

176. For an overview of some of the emerging governance in this area, *see* Jeff Merritt et al., *Governing Smart Cities: Policy Benchmarks for Ethical and Responsible Smart City Development*, World Economic Forum (Jul. 2021), *available at* https://www3.weforum.org/docs/WEF_Governing_Smart_Cities_2021.pdf.

177. Eben Harrell, *Neuromarketing: What You Need to Know*, Harvard Business Review (Jan. 23, 2019), https://hbr.org/2019/01/neuromarketing-what-you-need-to-know#:~:text=%E2%80%9CNeuromarketing%E2%80%9D%20loosely%20refers%20to%20the,pricing%2C%20and%20other%20marketing%20areas.

178. Sharad Agarwal & Tanusree Dutta, *Neuromarketing and Consumer Neuroscience: Current Understanding and the Way Forward*, 42(4) DECISION, 457-462 (Nov. 2015), *available at* https://www.researchgate.net/publication/284234343_Neuromarketing_and_consumer_neuroscience_current_understanding_and_the_way_forward.

179. *Id*.

180. Samuel M. McClure et al., *Neural Correlates of Behavioral Preference for Culturally Familiar Drinks*, Neuron (2004) 44(2): 379--387, *available at* https://pubmed.ncbi.nlm.nih.gov/15473974/.

181. *Id*.

182. *Id*.

183. The Advertising Research Foundation encouraged its members to use neuromarketing technology in 2017. *Introduction to Neuroscience and Biometric Marketing Research Methods*, The Advertising Research Foundation (Aug. 2017), http://thearf.org/wp-content/uploads/2018/02/KAH-Neuroscience-FINAL-web.pdf.

184. For more information about the differences between fMRI and EEG, see Christoph Mulert, Simultaneous EEG and fMRI: Towards the Characterization of Structure and Dynamics of Brain Networks, Dialogues Clin Neurosci. (Sept. 2013), available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3811108/.

185. *See A Brief Overview of the Federal Trade Commission's Investigative, Law Enforcement, and Rulemaking Authority*, FTC (Oct. 2019), https://www.ftc.gov/about-ftc/what-we-do/enforcement-authority.
186. *NMSBA Code of Ethics*, NMSBA (last accessed Jun. 17, 2021), https://www.nmsba.com/neuromarketing-companies/code-of-ethics.
187. *See* United Nations Convention on the Rights of the Child, General Comment on Children's Rights in Relation to the Digital Environment ¶ 42 (2021), *available at* https://docstore.ohchr.org/SelfServices/FilesHandler.ashx?enc=6QkG1d%2fPPRiCAqhKb7yhsqIkirKQZLK2M-58RF%2f5F0vEG%2bcAAx34gC78FwvnmZXGFUl9nJBDpKR1dfKekJxW2w9nNryRsgArkTJgKelqeZwK9WXzMkZRZd37nLN1bFc2t.
188. Charles N. Munyon, *Neuroethics of Non-primary Brain Computer Interface: Focus on Potential Military Applications*, Front. Neurosci. (Oct. 23, 2018), https://www.frontiersin.org/articles/10.3389/fnins.2018.00696/full.
189. Al Emondi, *Next-Generation Nonsurgical Neurotechnology*, DARPA (last accessed May 21, 2021), https://www.darpa.mil/program/next-generation-nonsurgical-neurotechnology.
190. Paul Tullis, *The US Military Is Trying to Read Minds*, MIT Technology Review (Oct. 16, 2019), https://www.technologyreview.com/s/614495/us-military-super-soldiers-control-drones-brain-computer-interfaces/.
191. *See* 2010 Defense Department Budget, *supra* note 170.
192. DARPA Public Affairs, *Six Paths to the Nonsurgical Future of Brain-Machine Interfaces*, DARPA (May 20, 2019), https://www.darpa.mil/news-events/2019-05-20.
193. Kristin Houser, *DARPA Is Using Gamers' Brain Waves To Train Robot Swarms*, Futurism (Feb. 8, 2020), https://futurism.com/the-byte/darpa-gamers-brain-waves-train-robots-swarms.
194. Michael N. Tennison & Jonathan D. Moreno, *Neuroscience, Ethics, and National Security: The State of the Art*, PLoS Biology (Mar. 20, 2012), https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001289#s4.
195. Matthew Pava, *Restoring Active Memory (RAM)*, DARPA (last accessed Sept. 25, 2021), https://www.darpa.mil/program/restoring-active-memory.
196. Anika Binnendijk, et al., *Brain-Computer Interfaces: U.S. Military Applications and Implications*, RAND Corporation (2020) 9, https://www.rand.org/content/dam/rand/pubs/research_reports/RR2900/RR2996/RAND_RR2996.pdf.
197. *Id*. at 22.
198. *Id*. at 23-23.
199. *See* Ragini Verma et al., *Neuroimaging Findings in US Government Personnel with Possible Exposure to Directional Phenomena in Havana, Cuba*, 322(4): 336-347 JAMA (Jul. 2019), *available at* https://jamanetwork.com/journals/jama/fullarticle/2738552?guestAccessKey=47486c47-c01c-47fa-8b6e-41fc69f29cf4&utm_source=For_The_Media&utm_medium=referral&utm_campaign=ftm_links&utm_content=tfl&utm_term=072319.
200. George J. Annas, *Military Medical Ethics—Physician First, Last, Always*, New England Journal of Medicine (Sept. 11, 2008), 359(11): 1087-1090, *available at* https://www.nejm.org/doi/full/10.1056/NEJMp0805975.
201. Munyon, *supra* note 188.
202. Annas, *supra* note 100.
203. Munyon, *supra* note 190.
204. Tennison, *supra* note 194.
205. *Id*.
206. Lucille Nalbach Tournas, *If Police Have Devices That Can Read Your Mind, How Does the Fifth Amendment Fit In?*, Slate (May 28, 2021), https://slate.com/technology/2021/05/brain-computer-interface-mind-reading-fifth-amendment.html.
207. Tennison*, supra* note 194.
208. Constitutional reform text and procedural documents *available at* https://www.senado.cl/appsenado/templates/tramitacion/index.php?boletin_ini=13827-19.
209. En histórica Votación, Aprueban Proyecto Del Ley Que Regulará Los Neuroderechos en Chile, La Tercera (Apr. 13, 2021), https://www.latercera.com/que-pasa/noticia/en-historica-votacion-aprueban-proyecto-del-ley-que-regulara-los-neuroderechos-en-chile/4IAQJIVHM5F75GRLAR2GQ27V24/.
210. Bill of Law Establishing Neuroprotection, *available at* https://www.senado.cl/appsenado/templates/tramitacion/index.php?boletin_ini=13828-19.
211. Nayef Al-Rodhan, *The Rise of Neurotechnology Calls for a Parallel Focus on Neurorights*, Scientific American (May 27, 2021), https://www.scientificamerican.com/article/the-rise-of-neurotechnology-calls-for-a-parallel-focus-on-neurorights/.
212. Law No. 19.451, *available at* https://www.bcn.cl/leychile/navegar?idNorma=30818.
213. Abel Wajnerman Paz, *Are Neural Data Protected by Bodily Integrity? A Discussion of the 'Organic' View on Neural Data Rights*, Neuroethics Blog (May 12, 2021), http://www.theneuroethicsblog.com/2020/05/are-neural-data-protected-by-bodily.html.
214. *Id*.
215. *See* Stacey Gray, *Always On: Privacy Implications of Microphone-Enabled Devices*, FPF (Apr. 2016), https://fpf.org/wp-content/uploads/2016/04/FPF_Always_On_WP.pdf.
216. *See* Jules Polonetsky & Jeremy Greenberg, *NSF Convergence Accelerator: The Future of Privacy Technology (C-Accel 1939288)*, FPF (2020), https://fpf.org/wp-content/uploads/2020/03/NSF_FPF-REPORT_C-Accel1939288_Public.pdf.
217. *See* NIST, Cybersecurity Framework (Apr. 2018), *available at* https://www.nist.gov/cyberframework.
218. *See e.g.* IBM's Multidisciplinary, Multidimensional Approach to AI Ethics (last accessed May 15, 2021), https://www.ibm.com/artificial-intelligence/ethics; *Artificial Intelligence and Ethics*, Microsoft EU Policy Blog (last accessed Nov. 1, 2021), https://blogs.microsoft.com/eupolicy/artificial-intelligence-ethics/; Sundar Pichai, *AI at Google: Our Principles*, The Keyword (Jun. 7, 2018), https://www.blog.google/technology/ai/ai-principles/; Jerome Pesenti, *AI at F8 2018: Open Frameworks and Responsible Development*, Facebook Engineering (May 2, 2018), https://engineering.fb.com/2018/05/02/mlapplications/ai-at-f8-2018-open-frameworks-and-responsible-development/.
219. *See e.g.* Mark Roman Miller et al., *Personal Identifiability of User Tracking Data During Observation of 360-Degree VR Video*, 10 Scientific Reports (Oct. 15, 2020), *available at* https://www.nature.com/articles/s41598-020-74486-y, showing that a pool of 511 de-identified participants experiencing less than 5 minutes of VR could be identified, based on biometric tracking, by a random forest with 95% accuracy.
220. Heller, *supra* note 103.
221. *See e.g.* Rufin VanRullen & Leila Reddy, *Reconstructing Faces from fMRI Patterns Using Deep Generative Neural Networks*, 2 Communications Biology (2019), *available at* https://www.nature.com/articles/s42003-019-0438-y.

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