The Ethics of Brain Wave Technology

Issues, Principles and Guidelines

CeReB: The Center for Responsible Brainwave Technologies

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Executive Summary

Over the last few decades, the ways in which people, computers, and devices interact is rapidly evolving to become far more dynamic and naturalistic. As an extension of that evolution, brain-machine computer interfaces (BMCI) are enabling new methods for human-machine relationships; we are moving from 'body-mediated' interaction, in which people must physically act in some way to initiate and / or control a process or device, to the possibility of 'mind-mediated' interaction, in which brain activity alone can support our interactions with computers, devices, and perhaps even other people.

Brainwave technologies provide one way to facilitate mind-mediated interaction by detecting and responding to the electrical fields generated by brain activity, enabling users to apply that activity to computer and device communication. Originally developed more than a century ago, the underlying mechanism - known as electroencephalography or EEG - has long been used in medicine and neurology for both research on brain function. and for the detection of specific neurological disorders such as epilepsy. Over the last decade or so, however, the technology for EEG detection and interpretation has rapidly been moving from the medical lab to consumer devices.

As an emergent technology, brainwave technology offers consumers new mechanisms for enhancing and expanding the range of human-device interactivity as well as new insights into their own mental functioning. For those developing consumer-oriented brainwave technology, these capabilities create new challenges for enabling its safe and effective adoption, including consumer knowledge, privacy, agency and autonomy. In addition, it places a responsibility on all participants in brainwave technology to foster and engage in an ongoing dialogue about how the technology evolves.

Purpose of this White Paper

This white paper has been published by CeReB: the Center for Responsible Brainwave Technologies to assist in identifying some of the ethical issues raised by the emergence of brainwave technology in consumer-oriented devices, and to propose principles and guidelines for proactively addressing these as this technology continues to develop.

Both developers and consumers have important roles to play in how brainwave technology unfolds, ideally within the context of an informed dialogue about the technology and the associated ethical issues. The goal of CeReB and this white paper is to assist the wider community in identifying, framing and discussing those issues.

About CeReB

CeReB: the Center for Responsible Brainwave Technologies is a not-for-profit, non-partisan body dedicated to providing ongoing research and guidance regarding best practices in the field of consumer brainwave technology. Its members include experts in a wide range of disciplines including computing science, engineering, cognitive and neuropsychology, information and neuroethics, and brain-machine interfaces.

Please see the section entitled “The Center for Responsible Brainwave Technologies” for additional information on CeReB, its mandate, activities, and contact information.

Acknowledgements

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"*It is not enough to have a good mind; the main thing is to use it well.*"

Rene Decartes

Introduction

If you've ever wondered about what it would be like to control something in your world purely by thinking about it, you're not alone. It's a long-standing and very compelling fantasy, one that creates a magical connection between our ephemeral inner lives (the "stuff of thought") and the material world.

Brainwave technology is beginning to bring that fantasy into reality. By detecting and responding to the electrical activity generated by the brain, brainwave technology offers users the ability to harness that activity in a variety of ways. From controlling external devices to providing insight into our own mental activity, brainwave technology has the potential to significantly impact our lives and well-being.

Brainwave technology is an emergent technology, part of the still largely uncharted frontier of brain-computer interfaces and communication. As an emergent technology, it offers the excitement of discovery and untapped potential to those who research, develop and use it. However, because it provides a window into our mental processes - processes that have long been regarded as private and privileged - brainwave technology also places ethical responsibilities on those who wish to develop and utilize it.

It is the recognition of these responsibilities that has led to the formation of The Center for Responsible Brainwave Technologies (CeReB). Made up of a consortium of experts in a wide range of disciplines including computing science, engineering, cognitive and neuropsychology, information and neuro-ethics, and brain-machine interfaces, CeReB seeks to establish guidelines for the ethical development and use of consumer-oriented brainwave technology.[1]

This white paper has been developed to explore, and provide a framework for dealing with, the ethical issues that arise from the emergence of consumer level electroencephalography (EEG) technology. Although some of the questions this paper raises can be seen to have analogues in other consumer areas (such as devices that capture physiological data), the nature of EEG information and its potential to provide insight into mental functioning make it, arguably, a special case.

[1] Other groups have also identified the need for such guidelines in emergent technologies. One such group is MATTER, which recognizes "the need to consider and respond to social, ethical and environment issues" in emerging platforms such as nanotechnology. See http://www.matterforall.org/about-us.

Brains, Thoughts, and Machines

Communication and device control has always been "body mediated", requiring some form of motor-activated interface between the device and the user. Until recently, people could only communicate or control external devices by performing physical actions, chiefly through their hands, and more recently through their voices and eye movements. This has led to a dependency on a person's ability to generate and calibrate those actions, sometimes very precisely. Those unable to initiate or control physical movement experience significantly diminished agency and autonomy.

But what if the we could remove the need for physical action as a requirement for interaction with computers, devices and perhaps other people? What if we could provide a direct method of engaging and interpreting the brain, mind, or thoughts of an individual as the source of action? This is the domain of brain-machine computer interfaces (BMCI).

Brain-Machine Computer Interfaces

Brainwave technology is part of a growing area in BMCI that seeks to enable the control of machines and devices directly through brain activity alone.[2] That activity can be harnessed at the level of specific neurons - the cells that make up the brain - or, in the case of brainwave technology, through the electrical fields generated by the collective activity of larger areas of the brain.

By 'liberating' device control from the constraints imposed by physical action, BMCI essentially extends the reach of the brain beyond the boundaries of the body to enable direct control over both local and remote devices. Consequently, BMCI has significant implications for human agency and autonomy by, for example, enabling those who might have been previously unable to initiate movement in their own bodies - through paralysis or degenerative neurological or muscular diseases - to control devices supporting communication, environmental control, and movement.

These capabilities will eventually be available to all of us, transforming not only how we interact with the machines in our environment, but also, perhaps, our notions of what is ultimately humanly possible.

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[2] An excellent definition and review of brain-computer interfaces by Leuthardt et al (2009) is available from the National Centre for Biotechnology Information at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2920041.

Some of the ethical concerns associated with more invasive forms of brain-computer machine interfaces are discussed in "Clinical ethical concerns in the implantation of brain-machine interfaces: part I: overview, target populations, and alternatives." In IEEE Pulse. 2013 Jan-Feb;4(1):28-32. View the abstract at: http://www.ncbi.nlm.nih.gov/pubmed/23411437.

BMCI - An Emergent Technology

Although rapidly moving forward, BMCI is still in its infancy. Since it offers new ways of supporting human-device interaction, BMCI can be classified as an 'emergent technology'.[3]As is typical of emergent technologies, the development of BMCI is highly innovative and potentially transformative, not readily fitting into existing social and regulatory concepts and frameworks. Also typical of emergent technologies, BMCI is at the leading edge of the convergence of several streams of research and industry development, including neuroscience, robotics, and artificial intelligence.

The Role of Emergent Technologies

Given its transformative nature as an emergent technology, BMCI has an important role to play in the development of new ways of enabling human-machine interaction. Emergent technologies are, by their nature, catalysts. They offer new insights, drive new visions, and foster new potentialities. They redefine existing notions of what is possible. By bridging existing disciplines, emergent technologies foster interdisciplinary dialogue, sparking new conversations. They spur innovation, enable new ways of thinking, and consequently, identify new opportunities.

The Challenges of Emergent Technologies

For those concerned about the human impact of innovation, emergent technologies also offer significant challenges.[4] They often move very quickly, making their social and technological impact difficult to anticipate. They challenge existing social norms and mores, often forcing people to re-examine their values and perspectives. Furthermore, because their consequences are often unanticipated, emergent technologies place a special responsibility on those involved with them to proactively consider the implications of their development.

Brainwave Technology

Brainwave technology is a type of BMCI that links brain activity to computers and devices, enabling a user to view their own brain activity and/or use it as a method of controlling those devices. This is possible because all brains generate electrical activity from the action of neurons, cells in the brain, as they transmit signals back and forth between brain regions. The

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3 George Vialotsanos, the Canadian Research Chair in Innovative Learning and Technology, has provided a good definition of emergent technologies at http://www.veletsianos.com/2008/11/18/a-definition-of-emerging-technologies-for-education.

4 For a recent examination of the ethical issues associated with brain-computer interfaces, see: "Ethical issues in brain-computer interface research, development, and dissemination", Journal of Neurologic Physical Therapy, 2012 Jun;36(2):94-9. The abstract can be viewed at the National Centre for Biotechnology Information's website at http://www.ncbi.nlm.nih.gov/pubmed/22592066.

changes in the electrical potentials of these neurons can be measured over time to generate a pattern of electrical activity. The detection of the electrical activity generated by the brain as it functions is known as electroencephalography or EEG.

When electroencephalography is conducted over time, a pattern emerges that shows that the recording is, in fact, made up of a number of different frequency bands, or wavebands, usually referred to as Delta, Theta, Alpha, Beta, Gamma, and Mu. The combination and relative abundance of each waveband at any given moment can be an indication of mental activity (*e.g.* degree of concentration), mood, state of mind, or neurological disorders. For example, Delta wavebands (0 - 3 Hz) are generally produced in the front part of the brain in adults, and in the posterior (or back) areas of the brain in children. They are associated with specific sleep stages in adults, but may also be associated with deeper brain lesions or damage. Alpha wavebands (8 - 12 Hz) are produced in the posterior regions when awake and centrally at rest, and are associated with relaxation and the control of inhibition. Beta wavebands (12 - 30 Hz) are often associated with concentration, alertness, and anxiety, but can also be indicative of the presence of drugs such as benzodiazepines. Higher levels of activity in Gamma wavebands have been indicated in attention and associative learning. Mu wavebands (8 - 13 Hz) are associated with the normal, synchronized activity of motor neurons (neurons involved in movement).[5]

Although it is clear that there is a correspondence between EEG activity and particular types of brain functions, a precise understanding of these relationships has not yet fully developed. Simply put, there is still much that remains unknown.

Detecting and Using EEG - From Medical Labs to Consumers

Historically, the detection and interpretation of EEG signals required highly specialized equipment and expertise, and was generally restricted to medical and research labs. Now, EEG signals can be captured inexpensively and interpreted by consumer grade products from firms such as Emotiv, InteraXon, and NeuroSky. This has enabled EEG technology to move out of the laboratory and into the hands of consumers, and, as a result, has created both opportunities and ethical challenges for developers and consumers alike.

The Components of an Brainwave (EEG) System

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[5] There is a great deal of information on EEG available online that range from simple to highly technical in content. The following provide introductory overviews:

http://www.medicine.mcgill.ca/physio/vlab/biomed_signals/eeg_n.htm;

For a more technical examination of EEG, see:

http://web.cs.dal.ca/~tt/CSCI690611/eeg_intro_lecture.pdf;

http://www.psych.nmsu.edu/~jkroger/lab/EEG_Introduction.html;

http://www.scholarpedia.org/article/Electroencephalogram.

Whether in the lab or at home, EEG technology generally involves the following components:

1. A detection system to capture the EEG activity generated by the user. This is an array of EEG detectors (highly sensitive voltmeters) embedded in a surface applicator, often in the shape of headband or scalp cap.

2. A system for capturing, storing and/or displaying EEG activity as it is generated.

3. A method for analyzing and interpreting EEG activity, using specialized computer programs.

4. A method for responding to the EEG activity, whether that response is to display and/or graph the EEG or use the activity as input to an application. Applications can range from providing feedback to a user to initiating and controlling specific applications such as computer software or external devices. An example diagram of an EEG system is provided below.

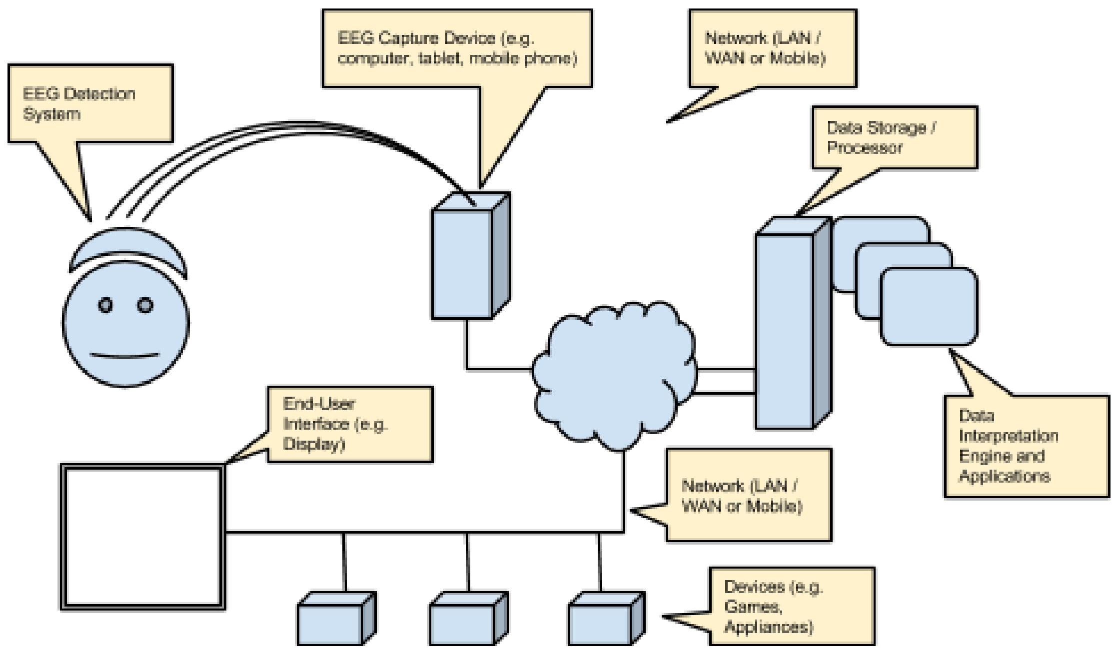

Figure 1: Diagrammatic Representation of EEG System

Differentiating Medical and Consumer Level EEG Devices and Systems

Medical practitioners have used EEG for many years, most often as a method of determining the presence of some form of neuropathology, such as epilepsy, in the brain of the patient.[6] Conditions such as epilepsy can generate signature patterns of EEG activity, which may lead to diagnosis, intervention, and treatment. EEG has also often been used in research to detect

6 For a short, readable overview by the U.S. National Library of Medicine and the National Institute of Health on how EEG can be used clinically, see: http://www.nlm.nih.gov/medlineplus/ency/article/003931.htm.

particular states of brain function, such as levels of arousal, relaxation, and sleep.

Medical uses of EEG are highly targeted and rely on the precise measurement and interpretation of EEG to provide specific insights into mental functioning and affective (emotional) states. These uses have significant consequences for the patient if not performed well or accurately. Consequently, the medical use of EEG should, and does, fall under a fairly strenuous regulatory regime that deals with private health information.

Consumer uses of EEG are usually far less precise, providing more generalized insight into mood, arousal, concentration, relaxation, and sleep. Consumer level EEG (such as the devices from Emotiv, InteraXon, and NeuroSky) are part of the growing intersection between the consumer, their own body-generated information, and, in some cases, social networks. This can be seen in the rapid emergence of the “quantified self” movement, through which people capture, interpret, and share their own bodily-generated data.[7]

Currently, consumer level EEG enables access to what was formally medical technology and knowledge, empowering those making use of this information to proactively attempt to create better lives. It seems clear, however, that the capabilities of consumer EEG devices are rapidly evolving, and will eventually match and perhaps surpass the capabilities offered by medical EEG devices. This suggests that the insights afforded by consumer level EEG will eventually be available to the general public, and without an adequate understanding of the consequences, the technology may allow for the unintended disclosure of sensitive information and the misinterpretation or misuse of that information.

As interest in brain-computer interfaces grows, and as their presence and use expands and becomes increasingly accessible to consumers, the ethical questions surrounding BMCI technology become increasingly pressing. *We strongly believe that, as participants in this emergent technology, we have an obligation to proactively assess and respond to these questions.*

Current and Potential Consumer Applications of Brainwave Technology

As described, brainwave technology detects, and makes use of, the electrical activity generated by the brain. This provides a direct link between brain function and responses provided by the brainwave application, the promise of ‘thought-controlled’ computing.

The usefulness of EEG arises from predictable relationships between specific EEG patterns and specific types of brain activity. If a specific EEG pattern can be reliably detected in response to a particular brain state or thought, then the potential exists to use that pattern to initiate and/or control an event or process. As the understanding of the relationship between brain activity and

7 For a comprehensive review of sensor technology and quantified self movement, see “Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0”, Swan, M (2012), Journal of Sensor and Actuator Networks, 1, 217-253, available at: http://www.mdpi.com/2224-2708/1/3/217/pdf.

specific EEG patterns grows, so does the potential for controlling such processes. This potential is ultimately limited by the sensitivity or resolution of EEG detection and the ability to reliably interpret and link specific EEG patterns to specific types of brain activity, whether consciously generated or not.

In order to discuss the ethical questions associated with brainwave technology, we will first briefly explore some of the current and potential consumer applications of the technology as a way of identifying some of the issues that emerge from its application.

Consumer Applications

The range of consumer applications to which brainwave technology is applied currently tends to focus on feedback related to emotional and attentional states, as well as emerging applications for interface and object control. For example, current applications provide real-time feedback on brain activity through EEG measurement, as well as gaming augmentation and device control applications. Other applications offer affect and cognitive functioning assessments that not only monitor areas of cognitive function such as alertness, concentration and emotional state, but also enable users to improve these through feedback.

An emerging and controversial consumer-oriented application of EEG technology is neuromarketing,[8] in which the cognitive and affective (emotional) state of an individual is monitored as a mechanism for improving marketing insight and opportunities. These types of uses raise challenging questions about the nature of EEG data, the information it currently and potentially provides, and the nature of consumer understanding and consent to the use of EEG data.

Those providing consumer-oriented EEG applications have also recognized the potential for enabling other companies and users the ability to harness their platforms by providing third party tools such as software development kits (SDKs). This enables third parties to access the EEG data generated by the devices and build their own feedback, interpretive, and control applications.

As noted earlier, one interesting consequence of more affordable, consumer-level physiological sensors and interpretive applications is the rise of the “quantified self” movement, in which participants actively seek to post, share, comment, and learn from other participants’ data and experiences. This type of cultural movement can be an extremely powerful, and empowering, method of gaining insight into – and perhaps some measure of control over – the participants' physiological, and ultimately behavioural and therapeutic responses. In other words, it can significantly contribute to participants’ personal and cultural agency.

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8 For an engaging read on neuromarketing and its application, see http://www.telegraph.co.uk/science/science-news/9984498/Neuromarketing-can-science-predict-what-well-buy.html.

For a more detailed examination of some of the ethical and professional issues raised by neuromarketing as a practice, see Fisher et al’s 2010 review in the Harvard Review of Psychiatry at http://www.telegraph.co.uk/science/science-news/9984498/Neuromarketing-can-science-predict-what-well-buy.html.

Ethical Considerations

As in any context in which personal information is shared, the disclosure of that information may lead to the risk that the information will be accessed, interpreted, or used in ways that were not intended or foreseen by the participants. That risk may be exacerbated with neurological and physiological data for a number of reasons.

First, the data being shared may carry information that is not fully understood by either participant or the healthcare community (for example, as yet unknown indications of specific predispositions or diseases). Second, the shared data could potentially be cross-correlated with other information available about the participant that may contribute to the intentional or unintentional identification of the product user or disclosure of health or psychological status to third parties (for example, employers or health insurance companies). Finally, the sharing models used by sites sharing bio-generated data are often primarily aimed at maximizing participation, not protecting privacy. Participants may not fully understand the implications or consequences of a specific act of data sharing.[9]

An additional consideration is ensuring that any device developed to collect neurological or physiological data is safe and can be effectively used by the consumer. Consumers should have a clear understanding of how to apply the device, its capabilities and limitations, and any identifiable risks involved with its use.

We believe, therefore, that those involved in creating and utilizing consumer level brainwave technology have an ethical responsibility to educate both users and the general public on brainwave technology and its evolution, the nature of the data generated and the mechanisms used to interpret it, and the potential consequences of its use and misuse.

Commercial and Workplace Applications

As with consumer-oriented applications, there is a broad range of commercial uses for EEG technology, from device control to employee performance monitoring and enhancement. For example, EEG data could be monitored as a way to provide indicators for the affective and cognitive state of an employee, including level of alertness, fatigue, concentration, and cognitive load.[10]

Applications might also include enhanced security through biometric EEG identifiers, improvements in device control, workplace augmentation (for example, a desktop configuration

[9] The situation is somewhat analogous to that of social media sites such as Facebook, which have been used as a screening tool by potential employers. As another example, sharing information about one's level of physical activity through activity sharing sites could be used in actuarial evaluations over heart and stroke risks. Perhaps even more problematically, the information could also be used to make predictions about a given participant's daily routine and provide information regarding their residence and whereabouts during the day. In recognition of this, some sites provide a “privacy” range which prevents geolocation data from being uploaded.

[10] For a deeper exploration of how such a system might work, see “In-Vehicle Monitoring and Analysis System for Driver's Enervation” at: http://ijtel.org/v1n3/(61-66)CRP_0103P10.pdf.

that responds to the affective state of the employee), and employee productivity. A recent study, for example, demonstrates the use of EEG as a biometric signature, enabling access to a computing device.[11]

Ethical Considerations

While these uses could potentially result in benefits such as improved operational safety (e.g. assessing the level of fatigue while driving or operating heavy machinery), the use of brainwave technology in a commercial context raises questions about the nature of EEG data, its interpretation, consent for its use, and issues of short and long term privacy and confidentiality.

The stakes can be high, especially when hiring, promotion, or termination decisions are tied in some way to the data.[12]

We believe that a significant ethical burden is placed on organizations wishing to utilize brainwave technology in a commercial context to clearly and transparently identify the uses of the technology and the resulting data, educate users about the potential for downstream involuntary disclosure of sensitive information, ensure that consent and opt-out provisions are clearly identified and supported (without penalty), and protect the data at a level commensurate with highly sensitive personal information.

Consumer Medical and Mental Health Applications

EEG has long been used within medicine as a mechanism for insight into neurological and cognitive states, functions, and pathologies. Given the historical challenges associated with gathering and interpreting EEG data, these uses have generally occurred within controlled settings under the supervision of highly trained specialists. However, with the emergence of consumer-oriented EEG applications, the gathering, interpretation, and use of EEG data can now occur anywhere under the control of consumers and the applications they use.

As noted earlier, research has shown that EEG data can provide valid and valuable insight into certain aspects of brain function, including state of arousal, affective state, cognitive functioning,

[11] For an overview of how EEG technology could be applied in this context, see: http://www.livescience.com/39497-drivers-identity-verified-using-brain-waves.html. The abstract of an article describing the system by Nakanishi et al (2013) can be viewed at: http://www.inderscience.com/offer.php?Id=55965.

Also see “Using Brain Waves as New Biometric Feature for Authenticating a Computer User in Real-Time”, Mohanchandra et al (2013), International Journal of Biometrics and Bioinformatics, Volume (7) : Issue (1).

[12] The battle over what constitutes the legitimate use of commercial monitoring or surveillance is being played out in a broad range of contexts, from the use of randomized drug testing among athletes and commercial vehicle operators to the proposed use of video cameras on police weapons. Generally the tension is between the claims made for employee privacy and the employers' right to set operational standards; privacy concerns usually, but not always, triumph.

and regional levels of brain activity. As the sensitivity and resolution or quality of EEG detection increases, the levels of insight afforded by brainwave technology will likely only increase.[13] These insights can offer users the potential for many positive interactions with brainwave technology, both in terms of a general awareness of brain function and cognition, as well as the ability to shape and improve aspects of these. However, these insights also have important consequences for user confidentiality and privacy.

Ethical Considerations

Ultimately, the value of brainwave technology is predicated on the quality of the data being generated and the quality of the interpretation of that data. A consumer using an EEG application is, in effect, entrusting that the developer of that application has the knowledge and expertise to interpret the EEG data correctly, and that the claims being made about the interpretation are, in fact, accurate.[14] Since the data being generated is stored by the developer, often in 'cloud-based' storage facilities, there is the additional burden of protecting that data from unintentional disclosure, especially when the storage is in transnational locations.

We believe that the developers of consumer-oriented EEG applications that make any claims regarding the type and quality of consumers' mental health or levels of function have an ethical responsibility to ensure that the claims are not spurious, misleading or harmful, and that the methods used to support those claims (as embodied in the hardware and software of the application) are developed in accordance with acceptable standards regarding user safety, agency, and privacy. These are non-trivial responsibilities.

Biomedical Engineering and Disability Applications

For many people, one of the of the most exciting areas of research in brainwave technology is its use as an enabling technology for those with disabilities. For those with motor impairments, brainwave technology offers the possibility for users to control devices such as prosthetic limbs, motorized vehicles, and household appliances through brain activity alone. Brainwave technology offers the possibility of extending the 'reach' of users' mental activity far beyond the body to any connected device.[15]

[13] For example, there is some evidence that EEG can be indicative of neurodegenerative diseases such Alzheimer's Disease. For more information, see "EEG in Dementia and Encephalopathy" at: http://emedicine.medscape.com/article/1138235-overview.

[14] As an example of inaccurate claims, although not dealing explicitly with brainwave technology, a recent article in Physiological Measurement - in a review of smartphone sleep screening applications - suggested that existing sleep screen apps were not based on scientific evidence. See: http://iopscience.iop.org/0967-3334/34/7/R29/pdf/0967-3334_34_7_R29.pdf.

[15] For an in-depth discussion of current issues in EEG control over robotic devices and their potential for use with the disabled, see "EEG Based Brain-Controlled Mobile Robots", Bi and Liu (2013), Human-Machine Systems, IEEE T, Volume:43 Issue:2.

These possibilities challenge our conceptions of human capacity, and help to erode the distinction between abled and disabled. It also raises questions about the equitable distribution of the technology and the consequences of a divide between those who have access, and those that do not.

Ethical Considerations

The ethical implications emerging from this area of brainwave application are complex and challenging. What rights of access could/should be granted to those who need this technology but can't afford it? What role should developers play in democratizing access, for example by providing licensing options that allow for wider distribution of the technology? How does access to technological augmentation or enhancement change our conceptions of what it means to be human? To what extent do we need to prepare for these changes?

It is in the perceived intimacy of the emerging relationship between our brains, minds and machines that much of the perception - and misperception - concerning brainwave technology in the court of public opinion will likely be forged. Exaggerated promises are easily made, but not easily kept. Apprehension and fear are easily stoked, but not easily dispelled. What seems self-evident is that the absence of clearly stated, accurate, and verifiable information will leave a void to be filled by conjecture and misinformation.

We strongly believe that the brainwave development community should be actively engaged in dialogues that address questions of enablement and augmentation, both within the brainwave community itself as well as within the wider public discourse.

Collaborative Applications – Thought Sharing?

A common question related to the emergence of brainwave technology is the extent to which it can be seen as "mind-reading", a window onto the specific thoughts of an individual using the technology. If the technology can provide some measure of insight into what the person is thinking, can that insight be used as a method of communication and collaboration? Ultimately, can we communicate telepathically, by thought alone?[16]

There has been some research funding devoted to developing this possibility,[16] but it is far from being realized, especially within consumer applications. However, although the current state of brainwave technology does not provide enough resolution to allow interpretation of brain activity as a specific thought per se, the technology does enable observers to identify and/or make inferences about the affective, arousal, and cognitive state of a user. This information could be used within a collaborative application to provide context for, and enhance, other forms of communication, providing a much richer spectrum of emotional cues than that afforded by

[16] One research consortium actively involved in researching this question is "MURI: Imagined Speech & Intended Direction". For an overview of the topic and their research, see: http://cnslab.ss.uci.edu/muri/research.html.

accompanying emoticons (for example, interpreting a statement as a genuine or sarcastic comment largely depends on the emotional state of person expressing the comment).

Over time, it is likely that the resolution of brainwave technology, its capacity for accurately interpreting specific brain activity patterns as specific thoughts, will increase. In addition, given that brainwave technology is part of a dynamic system in which users can learn to view and influence aspects of their brain activity, brainwave-mediated communication seems indeed possible over the long term.

Ethical Considerations

The ethical implications for these types of applications are rooted in the same issues of access, privacy, and confidentiality as existing electronically mediated communication methods. Brainwave technology can be seen as a far more intimate form of expression, significantly challenging the distinctions between intentional and unintentional disclosure (the corollary might be the degree to which body cues unintentionally disclose mood or state of arousal during face-to-face communication). Developers must take this into account when designing such systems, and take steps to help the end user understand the consequences and implications of their use of such a system.

A recent experiment carried out at the University of Washington[17] appears to suggest that brainwave technology can not only act passively as a conveyer of information, but also as a method of acting on the recipient through transcranial stimulation, a so-called brain “writer”. In the experiment, one person was able to invoke a specific action (an involuntary finger movement) in another person by thinking about moving his own finger. Although the authors suggest that the downstream recipient can effectively ‘gate’ or control the ability of such a system to influence their own brain activity, the experiment raises challenging issues about the mechanisms needed to preserve individual agency and the integrity of the self.

There may well be circumstances in which a voluntary ceding of control over aspects of one’s own brain function are permissible, even desirable, but the safeguards to prevent abuse must be robust and foolproof. In addition, there may well be a significant potential for harm under conditions of repeated exposure to brain writing technologies, harm that is only revealed after a substantial amount of time.

We strongly believe that there must be an active, informed, and on-going dialogue between developers, research, and academic and user communities about the nature of brainwave mediated communication, especially when that communication includes the potential for “brain writing”.

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17 For more information on this “brain-to-brain” experiment, see: http://www.washington.edu/news/2013/08/27/researcher-controls-colleagues-motions-in-1st-human-brain-to-brain-interface.

The Nature of Brainwave (EEG) Data

In addition to the application of brainwave technology within specific contexts, there are aspects to the EEG data being utilized that, in and of themselves, may create issues for users. As noted earlier, although EEG data has not generally been considered to be robust enough to act as, for example, a biometric signature, there are indications that this may one day be possible. This has significant implications for how the data must be treated.

Ethical Considerations

When coupled with the possibility that EEG data may be indicative of specific pathologies (for example, dementia), the significance of its disclosure, intentional or otherwise, is also increased. Herein lies one of the greatest challenges associated with brainwave data: the extent to which future applications may be able to use existing data in as yet unknown ways.

The situation is analogous to that of DNA data. Information - such as the presence or absence of a predisposition to a particular illness - that is currently captured in DNA data may not as yet be identified or exploited. It is entirely conceivable that the data now available will eventually provide a rich source of information about a broad range of genetically endowed potentialities and predispositions. Knowledge of some of these by third parties might be benign, while knowledge of others may provide third parties with the power to do harm though discrimination and/or unsolicited intervention. The same may well be true of brainwave data.

We believe that the data generated, stored, and used by brainwave technology must be handled in a manner that reflects its current and potential sensitivity, both as a personal “signature” and as a conveyor of information about an individual’s capacity or level of functioning.

Summary: Contexts and Ethical Considerations Associated with Brainwave Technology

The following summarizes the contexts for the use of brainwave technology and the associated ethical concerns.

Context	Current and Potential Applications	Ethical Concerns
Consumer Applications	• Cognitive & affect assessment and improvement • Gaming • Device control • Neuromarketing • Third party development (SDK) • Other	• Lack of consumer awareness • Lack of consent to data collection • Claim accuracy with respect to measures, meaning and therapeutic efficacy • Unintentional / downstream disclosure of sensitive data • User privacy and confidentiality short, mid and long term
Commercial Applications	• Cognitive and affect monitoring • Employee performance monitoring and support • Intervention	• Lack of control over data usage, disclosure, longevity • Lack of consent to data collection • Unintentional / downstream disclosure of sensitive information • User privacy and confidentiality short, mid and long term
Consumer Medical and Mental Health Applications	• Cognitive & affect assessment and improvement • Issue diagnosis • Active intervention	• Lack of consumer awareness • Claim accuracy • Unintentional / downstream disclosure • User privacy and confidentiality
Biomedical Engineering and Disability Applications	• Cognitive & affect assessment and improvement • Enablement technologies such as prosthetics / exoskeletons • Human machine integration	• Cost and access • Enhancement vs enablement • Conceptions of human capacity • Conceptions of humanity itself
Collaboration Applications	• Conveying communication context • Cognitive & affect assessment • Thought-controlled (mind-to-mind) communication • Remote thought-based action invocation	• Involuntary ceding of control • Unintentional disclosure of sensitive information • User privacy and confidentiality short, mid and long term • Lack of consumer awareness
The Nature of EEG Data	• Evaluation of cognitive function (capacity, efficiency, etc.) • Evaluation of affect and states of arousal • Evaluation of patterns of cognition (response to stress, sleep, etc.) • Early indications of neuropathology • Biometric “signature”	• Unintentional disclosure of sensitive information • User privacy and confidentiality short, mid and long term • Lack of consumer awareness of downstream potential

These considerations can be broadly classed into the following categories:

1. **The integrity of the person**: Given that brainwave technology does provide some measure of insight into brain functioning, it offers a "window" into what has otherwise been hidden and viewed as privileged. The manner in which this insight is presented, interpreted, and shared can have significant consequences for an individual's perceptions and feelings of self-identity (the 'authentic' self), and how s/he is, in turn, perceived by others.

2. **Agency and autonomy**: Another consequence over the insight into brain function provided by brainwave technology is the degree to which an individual's agency (their ability to act) and autonomy (their ability to act free of coercion) are impacted. The degree of influence, both direct and indirect, of brainwave technologies in any given context must be actively considered by the developers and users.

3. **Safety**: Safety in the context of brainwave technology has a number of facets. Brainwave technology is relatively new, and its long term safety impact on users through consumer level devices is not well researched. A second and equally important safety consideration is the degree to which the claims made about the technology and its uses are accurate and reliable; this will have a direct impact on the faith consumers can have both in these claims and the decisions they make as a result of their use of the technology.

4. **Consumer consen**t: Since brainwave technology does provide access to what can be seen as highly personal information, the degree to which a consumer is capable of making an informed choice over whether to allow that information to be gathered, and how it will be used, will be critical to maintaining the user's personal integrity, agency, and autonomy.

5. **Privacy and confidentiality**: The nature of brainwave data means that the protection of that data, and the degree of control a user has over how that data is stored and utilized, will have important consequences for user privacy. Ultimately, brainwave technology must be robust enough to prevent unintended disclosure or interception of the data generated by the device, and/or the corruption of specific components by a malicious attacker.

6. **Development of brainwave technolog**y: The emergent nature of brainwave technology means that continuous engagement by all stakeholders in its development, including developers, users and the public, is an important objective.

The Ethics of Brainwave Technology

As our previous discussion of potential applications demonstrates, there are important questions about the potential of brainwave technology and how that potential is realized. As an emergent technology, brainwave applications push against several existing conceptual boundaries, stretching our understanding what our relationships with machines, others, and ultimately ourselves might mean in the future.

We believe that the key to ensuring that this potential is appropriately harnessed is to proactively develop a framework for discussing and developing the ethics associated with brainwave technology. This section of the paper will attempt to do just that and will introduce CeReB and its proposed role in this process.

Drawing on Existing Frameworks

As discussed earlier, one of the major challenges of emergent technologies is that they often straddle existing disciplines and cannot be easily categorized. As a result, emergent technologies often fall between the cracks of existing legal and regulatory statutes. However, we can nevertheless make some reasonable judgments about the nature of brainwave technology and the existing ethical frameworks that can be drawn upon for informing its ethical use and development.

<u>Where Does Brainwave Technology Fit within the Ethics of BMCI?</u>

Researchers and developers of other BMCI technologies - such as direct neurological implants - have identified a number of ethical issues that emerge when discussing their current and future potentials. Those potentials includes a far more invasive and radical integration of man and machine than brainwave technology promises, raising some particularly “tricky” ethical concerns.[18] These concerns include consent, loss of the ‘authentic’ self, technological dependency as integration becomes increasingly ‘seamless’, distinctions between enablement and augmentation/enhancement, the consequences of the availability of these technologies outside of controlled settings and “in the wild”, the divide between haves and have nots, and the role of BMCI in reshaping notions of what it means to be human.[19]

Within BMCI, brainwave technology occupies a middle ground between the invasiveness of direct-to-brain connectivity (such as direct-to-brain electrical implants) and applications that utilize body generated physiological signals as an input.[20] Although brainwave technology does

[18] Brain-Machine Interfaces Make for Tricky Ethics: ttp://www.wired.com/wiredscience/2009/02/brainmachine.

[19] For an excellent review of how the ethical issues associated with BMCI are viewed by those in the field, please see Nijboer et al.’s 2011 survey entitled: The Asilomar Survey: Stakeholders’ Opinions on Ethical Issues Related to Brain-Computer Interfacing.

[20] At the level of consumer devices, brainwave technology arguably does not currently fully fall within a biomedical

reflect, and provide insight into, the functioning of the brain, it does not impinge on the physical brain itself, and is generally of lower risk than an implanted device. Additionally, since it receives signals only, it can primarily be considered to be a "passive" technology.

Thus, the ethics of consumer-oriented brainwave technology can be viewed as related to other more invasive forms of BMCI, but distinct because of the reduced risk brainwave technology poses to the end-user and its passive nature when utilized as a unidirectional receiver of bio-generated data.

Fundamental Principles of Biomedical Ethics

There are many sources from which ethical principles for any given context or technology might be derived. Since brainwave technology does generate data that reflects biological processes, one possible starting point is biomedical ethics.

One dominant framework from which we may draw upon is Beauchamps and Childress' four principles of biomedical ethics.[21] These principles have been widely applied in biomedical contexts as a framework for developing ethical guidelines in a broad range of disciplines. They can be summarized as follows:

1. Autonomy: The right for an individual to make his or her own choices;
2. Beneficence: Act in the best interests of others;
3. Nonmaleficence: Do no harm;
4. Justice: Act with fairness and treat others equally.

These principles clearly reflect a medical context rather than a commercial one, but they do address, at a high level, many of the ethical issues identified in the previous section. One of the key issues they raise, as expressed in the principles of beneficence and nonmaleficence, is the balance of risk versus benefit. Establishing an effective balance between these will, to a large degree, better educate the public on the benefits and risks of the technology and its commercial development.

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context since the purpose, degree of accuracy, and the interpretation of the data do not reflect the use of EEG in a medical context. Many consumer-level devices gather and store bio-generated data for self-monitoring purposes, and enable the sharing of this information between users, and this seems to be broadly accepted by the user community.

[21] For an overview of Beauchamps and Childress' four principles in practice, see: http://www.utcomchatt.org/docs/biomedethics.pdf. Gillon also makes a strong case for Beauchamps and Childress' four principles as a framework for biomedical ethics, and argues for autonomy as first among these principles. Http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1733645/pdf/v028p00332a.pdf.

The broad adoption of these principles as a framework for specific ethical policies suggests that this type of approach, principled but not prescriptive, is an effective method for supporting the creation of, and adherence to, ethical standards.

Privacy Regulatory Frameworks

Many countries have adopted strong privacy and regulatory frameworks for information that is seen as personally identifiable (PII) and health related,[22] generally based on or reflecting the privacy principles established by the OECD.[23] These principles define the responsibilities of the organizations collecting PII and the rights of the provider with respect to what information is gathered and how it can be used. They include:

1. **Limit Collection**: Limit personal data collection to what is reasonably required and obtain that information lawfully and with the consent of the provider.

2. **Data Quality**: The personal data collected should be relevant to the stated purpose for its collection and should be accurate and up-to-date.

3. **Purpose**: The purpose for which the data will be used should be clearly stated and the data should not be used for other purposes without disclosure on the part of the collector.

4. **Use Limitation**: Data can only be used for the purposes specified by the collector.

5. **Security**: Protect that information at a standard - based on current best practices - that reflects its sensitivity.

6. **Openness**: The collection and use of the personal data should be transparent and open, and those providing the data must be able to verify the data and be able to contact the data controller.

7. **Individual Participation**: A provider of personal information must be able to confirm whether data on him/her exists, specifically what that data contains, and be able to challenge and or request data deletion, within a reasonable time frame and cost.

8. **Accountability**: Accountability must be established for compliance with the previous

[22] E.g. In Canada, personally identifiable and health information falls under the Personal Information Protection and Electronic Documents Act (PIPEDA). In the US, health information falls under the Health Information Portability and Accountability Act (HIPAA). Both acts provide strong and more-or-less technology neutral standards for when such information is to be protected and under what conditions is may be disclosed. These acts are often further bolstered by provincial and state standards such as the “Health Information Protection Act (HIPA) in Ontario.

[23] Organization for Economic Cooperation and Development. The OECD’s privacy principles are available at: http://oecdprivacy.org.

principles.

In sum, these principles are designed to prevent non-purposeful and non-consensual collection of personal data, a mandate of confidentiality through the protection of that data, and the rights of the data provider to request access to, update, or delete that data. In the case of medical data, specific privacy frameworks in most countries in Europe and North America have been developed that are stronger than general privacy regulations.

Failure to adhere to these principles can result in jurisdictionally defined penalties and sanctions, applied either by the regulatory body, through legal recourse, or both. Failure may also result in substantial reputational damage to the affected organization.

Privacy and Brainwave Technology

The data generated by consumer-oriented brainwave technology applications are clearly both personal and sensitive, although the sensitivity of the data is directly related to the degree to which it harbours information about the individual and specifics regarding his/her brain or cognitive functioning. Since this has been shown in medical contexts, it is reasonable to treat brainwave information as private and sensitive to - at a minimum - standards demanded by privacy legislation. It can also be argued that since brainwave data falls into a 'grey' zone with respect to health information, application developers should err on the side of caution and protect brainwave data at a level commensurate with current best practices in privacy protection approaches and technologies.

Recently, the U.S. Federal and Drug Administration (FDA) has issued new guidelines for mobile medical applications, which may have some downstream implications for brainwave technology.[24] Within the guidelines, the FDA provides three examples of applications with respect to medical device classification; those not considered to be medical applications, those that will be considered to be medical applications on a discretionary basis, and those that are designated to be medical applications. While applications generating and utilizing EEG data may be classified as medical applications by these guidelines, they are only classified as such if the data are intended to be used in "the diagnosis of specific diseases or conditions such as sleep apnea."[24]

Additional Regulatory Standards

Other relevant regulatory standards that should be considered with respect to developing brainwave technology include device hardware safety standards as well as software and

[24] The FDA guidelines were issued on September 25, 2013. An overview and link to the guidelines is provided at: http://www.fda.gov/medicaldevices/productsandmedicalprocedures/connectedhealth/mobilemedicalapplications/default.htm.

application security standards. For example, the Canadian Standards Association is one group providing standards for many types of products and devices, including electrical devices.[25]

Ethical Principles and Guidelines

Proposed Foundational Principles

Given the nature of brainwave technology and its relationship to the ‘intimacy’ of brain and cognitive functioning, we propose that the foundation of an ethical framework should be focus on the following principles.

Firstly, brainwave technology must respect the individual and his/her integrity both as a person, and as a community member. That focus on the integrity of the person is a reflection of what we believe to be the potential consequences - both beneficial and harmful - associated with increased insight into our mental processes, processes that until now have been inaccessible to direct observation and/or control.

For the purposes of discussing the ethics of brainwave technology, we believe that the integrity of the person is fundamentally dependent on the following four pillars:

1. **Agency**: The ability for a person to take action when required or desired in accordance with their volition. The concept of agency includes supporting the capacity, and the feeling, of being able to act. Enhancing agency therefore improves the ability of the user to envision a richer set of possible actions in a wider range of contexts.

2. **Autonomy**: The ability for a person to act in manner that is truly an expression of their own decision making, beliefs, and will, free from influence and coercion.

3. **Privacy**: The prevention of the involuntary disclosure of any information that is directly related to, or associated with, a person, including information pertaining to their life, identity, physical and mental states, and well-being.

4. **Safety**: The ability for a person to engage in a behaviour or interact with a device within known, and fully disclosed, risk parameters that fall within established safety guidelines.

Secondly, we propose that there is an obligation for those developing any technology to be clear and honest about what is known and not known about the technology, and to make claims that are reasonable and justifiable on the basis of existing evidence. Where evidence does not reasonably support a claim, the developer should acknowledge the absence of support.

[25] The CSA’s website is available at: http://www.csagroup.org.

Thirdly, we propose that those developing brainwave technology have an obligation to help users understand the technology and make informed choices about why, how, and when to engage with the technology.

Finally, we propose that the ethics of brainwave technology is dependent on the intent of the developers and users of brainwave technology, and that as this technology matures the degree of its potential impact will increase. *Therefore, although the evolution of emergent technologies can be extremely difficult to predict, developers must try to be cognizant of the evolution of their technology and proactively establish ethical frameworks and practices that take this evolution into account.*

Summary - Proposed Ethical Principles of Brainwave Technology

In summary, the ethical development of brainwave technology rests with the following foundational principles:

1. Respect for the integrity of the person, including agency, autonomy, privacy, and safety.
2. Honesty and clarity over any claims made on behalf of the technology.
3. Contributing to informed decision making on the part of the user.
4. Proactively engaging with and assessing the potential impact of the technology as it matures.

From Principles to Practice - CeReB Guidelines for Ethical Consumer Brainwave Technology Use and Development

It is one thing to state a set of principles, but it is another to apply those principles to real world situations without being overly vague, prescriptive, or burdensome. We certainly do not wish to hobble the brainwave industry, but we do want to help ensure that both the public, and those engaged with its development, have a meaningful set of guidelines to draw upon as they engage with brainwave technology.

It is in this spirit that CeReB are proposing the following ethical guidelines for those involved in utilizing or providing consumer-oriented brainwave technology. We believe these guidelines to be well-grounded and supportable by most practitioners.

Ethical Guidelines for Brainwave Technology

The following provides a summary of the proposed principles and associated ethical guidelines for developers of brainwave technology.

Principle	**Guideline**
Integrity of the person, including:	Developers should treat all users as an end, and not as a means to an end. As such, developers should not take advantage of, deceive, diminish or demean users in any way. Developers should always consider and treat users with value, respect and dignity.
Agency: The ability to take action	Brainwave technology should not inhibit or interfere with a user's ability to act when wishing to do so. Brainwave technology should also strive to enhance agency, increasing one's ability to envision and engage in a richer set of possible actions in a broader range of contexts.
Autonomy: The ability to act based on one's own volition	Brainwave technology should respect the autonomy of the user and the user's ability to take or avoid taking action. The technology should not coerce, or force, action on the part of the user, unless the user has explicitly consented to participating in contexts where such actions can be reasonably expected to be part of that context (e.g. gaming). In all contexts, the user should be able to immediately and safely terminate the session whenever he/she feels a need to do so.
Privacy: Protection against involuntary disclosure	All data generated by brainwave technology should be considered, and treated, as sensitive, and accorded a level of protection commensurate with that designation. All data collection, transmission, storage, and disclosure methods and mechanisms must meet, within reasonable considerations, the regulatory and best-practice standards set for sensitive data within the jurisdiction in which the brainwave technology is being used. As part of the conformance to accepted privacy standards, user consent to the collection of, and the control over, brainwave data must be a paramount consideration.
Safety: Use of the device falls within acceptable safety and security standards	The hardware, software, and data components of any brainwave system should be designed and developed with user security and safety as a top priority. This includes

	considerations regarding the physical, psychological, and affective consequences of short and long term exposure to the technology, in whole or in part. This should also include considerations to prevent or mitigate malicious interference or corruption of any component of the technology on the part of a determined or opportunistic ‘hacker’.
Honesty and clarity over any claims made on behalf of the technology	Developers of brainwave technology should be careful to clearly define and characterize the veracity of any claim they make with respect to the use of brainwave technology, based on the evidence reasonably available to them. They should be willing to revise these claims if evidence does not support, or directly contradicts, them. All claims should also be accompanied by an assessment of the confidence that the user should be reasonably expected to place in the claim, based on available evidence.
Contributing to informed decision making on the part of the user	All those involved in the application or development of brainwave technology should actively enhance users’ and the public’s understanding of the technology and its current and future implications. This participation can take several forms but should involve, at a minimum, providing plain language guides describing the application, its usage, data, consequences, potential outcomes, and user rights. Developers should also provide links to additional resources and material as appropriate.
Proactively engaging with and assessing the potential impact of the technology as it matures	As an emergent technology, brainwave technology is constantly evolving and is difficult to predict. Developers should make an effort to stay involved, not only with technical developments but also with the implications of these for the user community and with larger social and ethical issues. We therefore encourage developers to actively participate in the ongoing ethical discussion concerning brainwave technology and its evolution.

The Center for Responsible Brainwave Technologies - Purpose, Mission, Role, and Participation

CeReB: The Center for Responsible Brainwave Technologies

CeReB: the Center for Responsible Brainwave Technologies is a not-for-profit, non-partisan body dedicated to providing ongoing research and guidance regarding ethical standards and best practices in the field of consumer brainwave technology. It is devoted to acting in the public interest by fostering and supporting research and dialogue surrounding the ethics of consumer brainwave technology and developing clear, meaningful, and achievable standards for ensuring the efficacy of brainwave technology and safeguarding the agency, privacy, and safety of its users. CeReB also acts as a source for reliable information concerning brainwave technology, provides and promotes research and education on its relevant ethical issues, and works with brainwave companies to encourage the development of brainwave technology in a socially responsible manner.

In brief, the core mission of CeReB is to act as a body of excellence and best practices, to participate as a centre of stewardship in research and dialogue, and to help guide the ethical development of this technology.

Why CeReB? Why Now?

As the marketplace for consumer brainwave technology grows and new uses for the technology emerge, so too will fundamental questions about the ethical practices, roles, and responsibilities of service providers in this space.

These questions reflect the high pace of innovation in a new and emerging field of technology. As leaders in the development of brainwave technology, our challenge is to provide an ethical framework in which the affordances of brainwave technology can be met without stifling innovation, and without compromising consumers' privacy, safety, or agency.

It is in this time of early, rapid development that these issues should begin to be addressed by those involved with the technology, whether in academia, industry, government or consumers. CeReB aims to provide a framework and forum for that process.

CeReB's Activities

CeReB and its membership body act as a centre of excellence for understanding and guiding the development and use of consumer-oriented brainwave technology. CeReB will conduct its activities in a manner that supports its values without institutional, political, or commercial bias. These activities may include, but are not limited to:

Ethical Leadership: CeReB will strive, in collaboration with its communities, to continuously develop clear, meaningful, and achievable ethical standards for consumer-oriented brainwave technology that reflect best practices in ensuring privacy, safety, and efficacy.

Innovation: CeReB will actively promote innovation in the development of consumer-oriented brainwave technology in a manner that meets established ethical standards.

Regulation: CeReB will actively participate in the evaluation and development of regulations concerning the development of consumer-oriented brainwave technology as the need for these emerges.

Collaboration: CeReB will collaborate extensively with academic, industry, policy, and consumer communities to understand, articulate, and reflect the concerns and aspirations of these communities for brainwave technology.

Research: CeReB will participate in its own and collaborative research into the areas of privacy, transparency, safety, and consent in relation to consumer brainwave technology, with the goal of facilitating the development of industry-leading best practices in detecting, processing, transmitting, storing, and sharing brainwave-related data.

Education: CeReB will strive to actively inform its communities, partners, and the public of ongoing advances in brainwave technology and its current and potential implications for ethical standards and practices through conferences, public education and outreach, published works, and international collaboration. CeReB will make this information available for peer review as well as for public input and commentary.

Advocacy: In addition to actively promoting the ethical development and utilization of brainwave technology, CeReB will act as an advocate for responsible and ethical members of the brainwave community within international and local political and policy arenas.

Our Membership

CeReB's membership is composed of security and privacy experts, neuroscientists, academics, philosophers, research institutions from around the world, and companies involved in developing and/or utilizing consumer-oriented brainwave devices.

How You Can Participate

CeReB welcomes input from all those involved with the development, promotion and use of brainwave technology, including consumers and interested members of the public. You can contribute to the ongoing discussion concerning brainwave technology, or participate in CeReB itself.

Contribute to the Discussion

As CeReB moves forward, we will be developing several ways in which you can contribute to the discussion concerning the ethics of brainwave technology. These will include:

Website: CeReB's will be posting resources and research results to its website, www.brainwavecenter.org, as well as hosting ongoing dialogues regarding brainwave ethics.

Social Media: CeReB will utilize social media to disseminate information, increase awareness of its mandate and activities, and provide regular updates on major events and findings.

Conferences: CeReB will be participating in conferences related to brainwave technology and brain-machine interfaces to promote discussion and research concerning the ethics of brainwave technology. CeReB will also host its own conference regarding the ethics of brainwave technology, to which you are encouraged to attend.

Join/contribute to CeReB

If you would like to contribute to CeReB, either as an academic, industry player, or consumer, please let us know. You can apply to become a member under "members/become a member" or email CeReB though its website (again, www.brainwavecenter.org). Please let us know if you wish to be contacted by CeReB and you will receive our newsletter.

Contact CeReB

Email: ari.gross@brainwavecenter.org
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