Neuroethics and brain-computer interfaces (BCIs)

Eran Klein & C.S. Nam

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EDITORIAL

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1. Introduction to neuroethics and BCIs

Advances in brain-computer interface (or brain-machine interface) technology raise interesting and important ethical questions. BCI researchers encounter some of these questions, such as informed consent, during regulatory processes, such as institutional review board (IRB), animal use, or Food and Drug Administration (FDA) device applications. Ethical issues raised by BCI go beyond strict regulatory matters, and include broader concerns with autonomy, agency, responsibility, identity, and normality, and these questions are beginning to gain attention.[1,2] The *Gray Matters* report of the President's Commission for the Study of Bioethical Issues recently concluded that neuroscientific advance brings with it moral imperatives both to conduct research in ethically responsible ways but also to think deeply about ethical implications of new knowledge of the brain.[3] BCI technology is at the forward edge of neuroscience and provides a unique opportunity to explore such implications.

Neuroethics is an interdisciplinary area within the field of bioethics that has emerged in the last two decades largely in response to advances in neurotechnology.[4] Advances in neuroimaging, neuropharmacology, neurogenetics, neural transplantation, and neural engineering have led to concerted efforts to grapple with non-scientific challenges raised by the roll-out of these technologies. Philosophers, lawyers, neuroscientists, clinicians, social scientists, and others contribute – often from different and complementary disciplinary vantage points – to ongoing dialogue about ethical, legal, and social implications (ELSI) of neuroscience developments. The kinds of questions raised by BCI have a natural place within this larger conversation.

Discussion about ethical issues in BCI inherits a kind of orienting framework from this larger conversation in neuroethics. Work in neuroethics has come to dichotomize neurotechnologies in terms of information flow.[5,6] Some technologies take information *out* of the nervous system, such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), while other technologies send information *into* the nervous system, such as deep brain stimulation (DBS), neuropharmacology, and neural transplantation. The direction of information flow – gleaning information from the nervous system or using information to intervene in the nervous system – has emerged as a kind of

ethical heuristic in neuroethics: first determine the kind of neurotechnology at issue, then analyze its ethical implications. Although this rule of thumb may not yield simple solutions to complex problems, it has been helpful when particular kinds of neurotechnology travel with different families of ethical concerns. For instance, privacy tends to be an ethical concern raised by gleaning neurotechnologies, whereas issues of autonomy tend to be of relevance to intervening neurotechnologies.

Examples of the directionality heuristic outside of BCI are not hard to find. Functional MRI used to identify psychological traits ('brainotyping') is an example.[7] As a gleaning neurotechnology, fMRI technology can be seen to raise questions about privacy. What is the nature of the information gathered by means of this technology? Who controls or owns this information? How can it be legitimately used? What counts as a violation or transgression relative to this information? These are all concerns nestled within a broad notion of privacy. Conversely, a technology like transcranial direct current stimulation (tDCS) sends information into neural systems by means of neurostimulation, and as such tends to raise a different family of concerns centered on notions of decisional autonomy. How should the decision to get tDCS be made? What level of understanding of side effects or potential benefits is optimal (or minimally required)? Can pre-existing medical conditions limit who has access to this technology, for example individuals with cognitive impairment or severe mental illness? Should access to tDCS be regulated, akin to other medical therapies, or should it be available as a consumer product with which individuals can seek to 'enhance' themselves? These kinds of questions principally relate to autonomy and its exercise.

An important feature of BCI technology is bidirectional flow of information. Brain data collected by fMRI, EEG, or implanted electrodes (such as electrocorticography or deep brain stimulation (DBS)) are fed back *into the system* to achieve some goal, such as control of functional electronic stimulation (FES), a robotic arm, or a wheelchair. Closed-loop systems currently take different forms. For instance, a surface EEG BCI-based communication device uses EEG brain signals to control a spelling device.[8] The individual performing a spelling task might use perceptual feedback ('Did I move the cursor in the right direction?' 'Did I – by appropriately

attending to visually presented letters or words – select the correct language element?') to change brain activity for the next iteration. Other forms of BCI, such as an implanted DBS device for controlling tremor or depression that uses real-time recorded brain signals to adjust stimulation levels, also aim to close the informational loop. Rather than a DBS device providing stimulation at a constant level, BCI allows stimulation to be individualized to need – turning on or up when symptoms are present and turning down or off when symptoms are quiescent – thereby saving battery power and minimizing stimulatory side effects.

The bi-directionality of BCI information exposes the limited usefulness of the directionality heuristic. Consider the example of a closed loop DBS device for control of tremor discussed by Brown and colleagues in this issue. The possibility of such a clinical device will undoubtedly raise questions about both information privacy and autonomy. What kind of information *about the person* can be gleaned from measuring brain patterns associated with tremor or attempts to control the tremor? What can be inferred about particular intentions, desires, motivations, or personality traits? Conversely, how much control should an individual be allowed to exert over the stimulation level of a device, particularly if there are personal or public safety trade-offs at different stimulation levels (e.g. driving an automobile)? What is notable, when exploring these questions at any depth, is that the privacy and autonomy questions are intertwined.

An individual's sense of control over BCI output devices, such as DBS devices, wheelchairs, communication devices, will change as control over these devices shifts from conscious intentional control to computer algorithms or machine learning or some combination of the two. This change in control has implications not only for an individual's autonomy – the ability to make decisions and shape a life – but for privacy as well. Algorithms and recorded brain data will make 'the self' publicly accessible in unprecedented ways and thereby put pressure on existing norms governing privacy. Privacy and autonomy are not distinct ethical concerns raised by BCI technology, but are intertwined in complex and challenging ways because of the bidirectional flow of information. A simple directionality heuristic, while useful in some contexts, may not be up to the task for BCI technology.

2. Special issue contributions

The papers in this special issue were invited from individuals working on both empirical and conceptual approaches to ethical issues arising in BCI. Six articles were selected for publication after a two-step review process involving experts in BCI and in neuroethics. These papers span a wide range of concerns from conceptual analyses of identity, autonomy, responsibility, and disability in the context of BCI use to empirical studies of end-users with implanted neural devices and of research rationales in BCI publications. These pieces explore challenges that BCI researchers face individually and collectively, now or in the future.

As previously mentioned, Brown and colleagues describe a series of interviews with a subject participating in a trial of an implanted BCI-controlled DBS system for essential tremor. They argue that the design of BCI-based clinical devices will need to incorporate not just safety concerns, but will need to attend to ways that using a BCI-based device affects an individual's identity. BCI users may have very different expectations of BCI devices and may approach the trade-offs of using a BCI device differently. For instance, aesthetic, financial, and surgical concerns influence not just the decision whether to adopt a BCI-based device but how it is used, such as minimizing device activation in order to prolong battery life.

Glannon explores the role that BCI-based communication may play in end-of-life decision-making for individuals with disorders of consciousness. BCI may allow an individual in a minimally conscious state (MCS) and impaired communication to express a desire for or against life-sustaining therapies such as artificial nutrition and hydration (ANH). Glannon argues that fairness dictates that the end-of-life wishes of individuals functioning at the high end of MCS be accorded respect, much as the wishes of individuals with cancer or other chronic conditions are accorded respect. Near-term technical challenges of using BCI-based communication for consent to therapy – such as reliance on binary yes-no questions – need to be overcome. Nonetheless, BCI technology may provide a way for individuals with MCS to communicate their wishes and thereby advance their interests.

Wasserman and Aas consider BCI technology through a lens of disability theory. Will BCIs be designed and used to assist select groups with disabilities, be universally designed for widespread use, or some combination? The authors argue that the answer matters because BCI technology can both improve and undermine the interests of persons with disabilities. An assistive technology like a BCI-controlled exoskeleton will significantly improve an individual's ability to walk, but may do so at a cost. BCI devices as assistive devices single out individuals with disabilities and invite stigma and will undermine societal motivation to make environmental changes, such as sidewalk curb cuts for wheelchairs. The potential benefits and risks of BCI technology need to be considered not just in terms of individual function but in terms of impact on social inequalities.

Weinberger and Greenbaum consider how BCI devices that incorporate machine intelligence raise thorny

questions about legal culpability for device-related criminal acts. Who or what is responsible for untoward consequences that result from use of a BCI-based neuro-prosthetic? The user? The designer of the artificial intelligence controlling the BCI device? The device itself? The authors point out that the reliance of the law on notions of intentionality, voluntariness, and conscious control provides much less guidance in sorting out legal liability for BCI-mediated actions than one might hope. Much work still needs to be done at the intersection of law, artificial intelligence, and neural devices. Conducting this work against a backdrop of public fears of technology, as their analogy to Mary Shelley's Frankenstein alludes, only adds to the importance and difficulty of this task.

Specker Sullivan and Illes analyze a subset of publications in BCI to understand how researchers describe the rationales for studies involving human subjects. They examine how "rationale statements" relate to types of subject populations, types of BCI intervention, future clinical or non-clinical use of BCI devices, and common benchmarks for responsible conduct of research. They conclude that significant heterogeneity exists in how human subjects research is justified within published BCI studies. They recommend that BCI studies involving human subjects include: a statement explaining the choice of subject group, a statement of risk-benefit, citations supporting claims about the target population, and acknowledgment of potential dual or multiple uses of a BCI devices.

Klein and colleagues present results of a qualitative study on the use of BCI for treatment of psychiatric disorders. The authors conducted a focus group and semi-structured interviews with subjects implanted with deep brain stimulation (DBS) devices for depression or obsessive-compulsive disorder. Asked for their perspectives on the prospect of a future BCI-based psychiatric therapy, subjects expressed concerns about control over device function, the ability to give consent, effects on relationships with loved ones, and the impact on an individual's sense of authenticity. The authors conclude with recommendations for seeking end-user input in the development of BCI-based devices.

3. Conclusions and acknowledgements

This theme issue of the journal provides an introduction to ethics and BCI technology. The contributions contained here touch on a wide range of ethical issues, employ both empirical and conceptual methodologies, and engage researchers from across disciplines. This collection is not a comprehensive treatment of ethical issues raised by BCI technology, but an impetus for continuing important discussions within the field of BCI research about ethical, legal, and social implications of neurotechnology.

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Eran Klein
Center for Sensorimotor Neural Engineering and Department of Philosophy, University of Washington, Seattle, WA, USA
Department of Neurology, Oregon Health and Science University, Portland, OR, USA

C.S. Nam
Edward P. Fitts Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, NC, USA