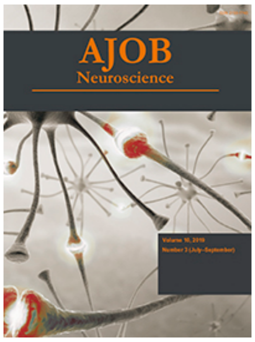

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Neuroethics at 15: The Current and Future Environment for Neuroethics

Emerging Issues Task Force, International Neuroethics Society*

Neuroethics research and scholarship intersect with dynamic academic disciplines in science, engineering, and the humanities. On the occasion of the 15th anniversary of the formation of the International Neuroethics Society, we identify current and future topics for neuroethics and discuss the many social and political challenges that emerge from the converging dynamics of neurotechnologies and artificial intelligence. We also highlight the need for a global, transdisciplinary, and integrated community of researchers to address the challenges that are precipitated by this rapid sociotechnological transformation.

Keywords: neuroethics; direct-to-consumer technology (DTC); artificial intelligence (AI)

INTRODUCTION

The young field of neuroethics recently celebrated its 15th anniversary. Here, we take stock of current trends in neuroscience and neurotechnology and describe the challenges that we predict these advances will pose for neuroethics over the next fifteen years. The notion of expansion is the overarching theme emerging from this analysis.

Neuroethics seeks to understand and navigate the ethical tensions and conflicts that arise in the research and application of neuroscientific knowledge and techniques. These conflicts exist at multiple levels, from unique individual cases to policies affecting large groups of people. While the underlying values at stake, such as human dignity, well-being, and justice, remain constant, the ways in which these values are understood and applied shift over time. Similarly, the types of problems neuroethicists explore evolve with social, scientific, and technological developments.

Three developments shaping neuroethics now and in the foreseeable future are:

1. Rapid and continuous increases in knowledge and technical capability, including not only advances in neuroscience, but also parallel developments in other fields, such as communications, data science, and machine learning.
2. The expanding global landscape of large-scale neuroscience research that generates increasingly diverse perspectives and greater access to knowledge, but also demonstrates the need for frameworks that are commensurate with divergent value systems.
3. Increases in commercial, military, and government applications of neurotechnologies that can ensure the development of, and access to, beneficial technologies, but potentially threaten individual protections and privacy.

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Here we explore some key features of these three technosocial transformations and their implications for neuroethics as an academic field.

RAPID TECHNOLOGICAL CHANGE

Profound advances in clinical neurosciences have been made during the last decade that, when coupled with computer technology and robotics, have resulted in a new era of neurotherapeutics. They have provided patients with motor deficits an ability to maneuver a robotic arm by thought, for example, and enabled the implementation of real-time, closed-loop technologies to detect and prevent seizures in epilepsy patients, even before individuals are consciously aware of them. At the same time, the availability of traditional biomedical data pertaining to an individual, such as heart rate and electroencephalography (EEG), has expanded to encompass gyroscopic and geolocation data from smartphones, as well as text content from social media activity. This broadening of data streams to include indicators of behavior has generated ethical tensions related to personal autonomy and personal privacy.

One of the key areas of rapid technology-driven change that relates to these tensions is technology for harvesting brain data and data on mental health. Neurowearables, such as EEG sensor headsets and brain–computer interfaces (BCI), are now being made available to consumers (Coates McCall et al. 2019). Online activity, including both the content and metadata from the "digital exhaust" it creates (Kreitmair, Cho, and Magnus 2017), can now be combined with data from a multitude of self-tracking devices that generate behavioral and physiological information, such as a person's location, heart rate, perspiration, breathing volume, and blood alcohol levels. Ingestible and implantable biosensors are able to detect and transmit information about a broader range of physiological and biochemical parameters (Rong, Corrie, and Clark 2017). Such multimodal data, among which brain data from wearable devices are just some, can be integrated with a wealth of other personal data, such as smartphone use, to construct a comprehensive representation of an individual's behavioral, physiological, digital, and neurological phenotype (Martinez-Martin et al. 2018).

This wealth of data may also be used by marketers, insurance companies, employers, and governments to monitor and influence our behaviors. Indeed, a major insurance company has ceased offering traditional life insurance policies in favor of "interactive life insurance," in which customers are offered incentives to hit targets on wearable devices (Barlyn 2018). Other unexpected, potential uses of such information are foreshadowed by a recent arson prosecution in which pacemaker data was used to show a suspect had been awake when he claimed to be asleep (Paul 2017). Increasingly, therefore, technology can be used both to monitor an individual's behavioral phenotype in ways never seen before and to use this knowledge to make predictions about future behavior. If wearable devices for measuring brain data were to become more precise in decoding information (e.g., with advanced machine learning such as deep learning), this capability could also extend to mental states such as intentions. This possibility raises issues regarding a person's cognitive liberty and privacy in ways that we have not seen previously and that are difficult to appreciate. This invites the question: Who should be permitted to have access to a person's neural and behavioral data? How should technologies of brain and behavior be designed? How should such data be collected, regulated, and disclosed? This becomes particularly relevant in societies in which civil liberties are not adequately protected, such as in China, where the social credit system that is scheduled to be rolled out and fully implemented in the next 2 years is based on mass surveillance of citizen behavior (Griffiths 2019).

The development of intelligent computing systems, such as artificial intelligence (AI) and machine learning, has dramatically increased the ability to use these big data to predict and diagnose mental illness and behavior. On the one hand, there may be significant advantages for health care systems, such as an improved ability both to detect clinical problems early and to increase access to medical expertise. On the other hand, these developments may undermine the patient–provider relationship if the clinical encounter becomes one of semi-automated responses to particular data inputs. Furthermore, algorithmic bias, that is, that algorithms trained for machine learning with data that are prestructured by human history, tends to replicate biases represented in the data, highlighting the risk of injustice in opaque AI-driven decision making. Because the underlying algorithms are complex and often impenetrable for both patients and health care providers, questions of accountability and trust may arise between them (Nuffield Council 2018). While not yet in widespread use, another medico-legal application of brain data is forensic risk assessment in the justice system (Poldrack et al. 2018; Spranger 2012). Here, concerns regarding algorithmic injustice (Eckhouse et al. 2019), as well as the impact of methodological problems in neuroscience on the validity and legitimacy of using neuroscience data in courtrooms (Kellmeyer 2017), are increasingly pertinent. The relationship between abnormalities in neural data and conditions that are overrepresented among juvenile criminal offenders in particular, such as attention deficit hyperactivity disorder (ADHD), is not fully clear at present (Mordre et al. 2011). Should science be able to establish a causal connection, abnormal neural data could have social consequences that could be both beneficial and worrisome, such as encouraging preemptive intervention or incorporating additional conditions into forensic risk assessment.

Invasive and noninvasive forms of neurostimulation technology are also evolving rapidly, specifically the expanded use of adaptive closed-loop stimulation in various medical conditions, as well as the emergence of consumer and do-it-yourself devices. This technological development alters the ethical assessment of neurostimulation by altering the risk–benefit profile, the types of conditions that can be addressed, and the expense and therefore accessibility of the treatments. Adaptive or closed-loop forms of deep brain stimulation (DBS) could make this form of invasive neurostimulation better suited to conditions where symptoms are episodic. In fact, such a system has been approved for epilepsy. However, in bypassing the patient's conscious awareness, closed-loop systems may convey a sense of lack of control on the part of the user, which may be alienating for the user. At the same time, we see a trend of expanding the use of DBS for conditions that are not particularly well understood pathophysiologically, particularly in psychiatry, in underpowered clinical trials or even single cases. This trend needs to be monitored and critically examined, as this research often does not satisfy established scientific standards of incremental clinical research (Bittlinger 2017; Christen et al. 2014). Noninvasive forms of neurostimulation such as transcranial direct current stimulation (tDCS), transcranial magnetic stimulation (TMS), and focused ultrasound (fUS) are likely to be used more broadly. In addition, a still experimental neurostimulation technique using electric field interference has been heralded as a possible means of noninvasive deep brain stimulation (Lozano 2017; Grossman 2017). Important questions for neuroethics relating to safety, consent, access, and individual and group privacy arise.

The range of neuroethical questions raised by technological development is not restricted to questions about the clinical or social consequences of using these technologies. Instead, technological developments and discoveries in neuroscience pose fundamental conceptual challenges. A historical but ongoing example is the concept of brain death. The advent of mechanical ventilation in the 1950s provided new clinical options for patients with severe brain injuries and simultaneously generated a controversial area of philosophical inquiry, which remains unsettled more than 50 years after the publication of the Harvard Ad Hoc Committee report on brain death (Ad Hoc Committee of the Harvard Medical School, 1968). While the question of whom society recognizes as bearers of fundamental rights or moral agency has a long philosophical tradition, recent scientific developments have added urgency to determining answers to these theoretical considerations. Knowledge and techniques from neuroscience are already being used in discussions of animal minds, within existing debates over animal rights (e.g., Bailey and Pereira 2018). Once solely within the realm of science fiction, neuroethics is now grappling with questions about the moral status of human brain organoids (Farahany et al. 2018; Lavazza and Massimini 2018) and "intelligent robots" (Wallach and Allen 2008).

TOWARD A GLOBAL NEUROETHICS

Neurological and mental health disorders raise enormous challenges for societies in every part of the world. Such disorders represent the largest single cause of disability and the second largest cause of death globally (Feigin et al. 2017). The large investment in global brain initiatives recognizes that neuroscience has the potential to help meet the need to improve brain health and mental well-being.

A global perspective is therefore essential for neuroethics. Among the issues requiring a global perspective is the coordination of large-scale neuroscience research programs (Amadio et al. 2018; Grillner et al. 2016), the governance of ethically controversial brain-related research and interventions, the impact of AI-driven research and innovation in neuroscience and neurotechnology (Yuste et al. 2017), and the need for an inclusive vision in understanding and responding to the neurological and mental health impact of the critical global challenge of environmental changes (Cabrera et al. 2016).

Large, global, coordinated initiatives reflect the scale, size, and cost of the technology and the disciplinary complexity necessary to tackle these great challenges. In the past few years, seven national or regional brain research initiatives in the United States, the European Union, China, Australia, Japan, Korea, and Canada have joined together under the umbrella of the International Brain Research Initiative (http://www.internationalbraininitiative.org) (Illes et al. 2019; Grillner et al. 2016). Collectively, these initiatives represent a potential investment of more than US$7 billion in neuroscience research (Global Neuroethics Summit Delegates 2018). Many of the current projects in neuroscience require vast amounts of computing power, large and expensive platforms that cross numerous disciplines (e.g., physics, engineering, computer science, genetics), and large amounts of data or participants (Kandel et al. 2013).

Global coordination comes at a time when neuroscience is attempting to overcome a reproducibility crisis (Anderson, Eijkholt, and Illes 2013; Button et al. 2013; Eklund, Nichols, and Knutsson 2016; Kellmeyer 2017; Munafò et al. 2017). The field is also working to improve transparency and to fast-track advances by introducing data sharing platforms to make data open-access (e.g., Neuro cloud consortium and Neurodata without borders initiative (Grillner et al. 2016; Canadian Open Neuroscience Platform [conp.ca])). Open-access data sharing introduces some additional technical and procedural challenges. It requires a coordinated effort, with the creation of data platforms, international standards, and standard operating procedures for sharing data such as coordinated data production and rigorous standards for data quality.

This investment of time to format and organize data is considerable and may be prohibitive. The activity is not straightforward, is often unfunded, and may not be recognized as part of a researcher's output or contribution. In addition, traditional practices, such as intellectual property restrictions, present further challenges to the goal of global open access.

The collaboration and sharing of data across many different nations and cultures raise additional ethical challenges. Navigating and respecting cultural differences that emphasize different ethical principles and values while staying within the ethical guidelines of one's own context is a hurdle that a globalized neuroscience will need to consider. This will require cross-cultural conversations about shared and divergent ethical priorities in order to harmonize ethical standards across collaborating countries. Given the different value systems and cultural traditions, arriving at convergent or compatible ethical frameworks will be a challenge. It will require an ongoing conversation in order to identify shared values as well as divergent priorities. The Global Neuroethics Summit that was held in 2017 and 2018 in South Korea has already begun this important conversation (Global Neuroethics Summit Delegates 2018).

There is also a need for global focus on guidelines for emerging forms of brain interventions. Given the checkered history of psychosurgery, concerns have been voiced about ensuring that new therapies are developed in a responsible and careful manner so as to protect patients both from ineffective or unsafe treatments, and from a backlash that might imperil useful treatments (Cabrera et al. 2018; Wind and Anderson 2008). One response has been the effort to develop international consensus guidelines for the field (Nuttin et al. 2014). Considerable variation exists among countries, and even within countries, with respect to laws governing neurosurgery for psychiatric conditions. This raises the issue of patients crossing borders as they seek jurisdictions with more relaxed rules (Psychosurgery Review Board 2012). Neuroethics can play a role in understanding and seeking to bridge the divergences in values among jurisdictions that may make international consensus on appropriate governance structures and principles challenging.

Another central issue for neuroethics is the need for a global vision to respond to collective anthropogenic threats, such as those posed by environmental changes (e.g., climate-change, mass-agriculture, and land-use issues), political actions (e.g., warfare and forced displacement), economic conditions (e.g., income inequality and poverty), and social dynamics (e.g., aging populations). It is increasingly clear that such large-scale human-made threats pose major risks and challenges in the near term, which, among other dimensions of human well-being, will have inevitable consequences for brain development and mental health. Justice and the practical need to galvanize the world to respond collectively demand an inclusive vision. One example of efforts in this direction is the emerging global mental health movement that advocates for culturally appropriate mental health care that can reduce mental disorders across all nations and peoples, particularly those from lower income countries and socially marginalized populations (Collins et al. 2011; Tomlinson et al. 2009). This movement has shown that the majority of research is conducted in the highest income countries, while mental disorders remain largely underdiagnosed and undertreated in low- and middle-income countries (Hanna et al. 2018; Schumann et al. 2019).

Across the world, there is a tendency to devote scarce resources to the more visible, immediately life-threatening health problems, while neglecting mental health concerns, which are often chronic conditions, poorly understood, and multifactorial. Humans develop in an environment that profoundly influences brain structure and function, with intricate interdependencies between biological, social, and cultural factors. Research into how these factors shape brain health, resilience, and vulnerability is being enhanced by the accumulation and analysis of large data sets of physiological and behavioral data that can be gathered using wearable devices, advanced neuroimaging, and other techniques. As methods for mining and using these data advance, so will their role in the world of policy and regulation. The politics of which populations and which types of environmental exposures are studied are crucial, given that the knowledge obtained will hopefully be useful to encourage appropriate and efficient responses (WHO 2005). At the same time, while efforts to target at-risk populations for neuroprotection are compelling, they come with the potential for intrusive paternalism, particularly by employing methods from behavioral economics such as nudging, and the stigmatization of recipient groups. The need for an inclusive, cross-cultural global neuroethics is clear as part of the collective response to the challenges of brain and mental health worldwide in the current era of rapid and large-scale technological and anthropogenic change.

INVOLVEMENT OF COMMERCIAL, MILITARY, AND OTHER LARGE-SCALE INVESTMENTS IN RESEARCH

In terms of large-scale investments in neurotechnological research and development, the main sectors are (1) private commercial, that is, neurotech startups or medical device companies that develop neurotechnology; (2) military research organizations, such as the Defense Advanced Research Projects Agency (DARPA) in the United States (Miranda et al. 2015); and (3) public research agencies such as the National Institutes of Health (NIH) in the United States, specifically through large-scale funding initiatives (e.g., the U.S. BRAIN Initiative, the Canadian Institutes of Health Research in Canada [CIHR], or the European Union's Human Brain Project). All of these sectors have long been involved in developing and disseminating technological innovations.

The military sector and the public research sector were notable drivers and funders of neurotechnological research and development (R&D) when neuroethics emerged as an academic field; the sector of commercial or direct-to-consumer neurotechnology has rapidly expanded and gained in importance in recent years (Ienca, Haselager, and Emanuel 2018; Kellmeyer 2018).

Consumers can now purchase on the open, largely unregulated, market technologies that record and upload brain activity to smartphones or stimulate the brain with small amounts of electrical current—technologies that were once the exclusive instruments of physicians for diagnosing and treating brain disorders (Wexler 2015; Wexler 2017). These direct-to-consumer neurotechnologies are marketed as ways to optimize brain fitness, improve cognitive functions such as memory and attention, and even improve autonomy among persons disabled after injuries to the central nervous system (Coates McCall et al. 2019). This represents a substantial market: Wearable technologies are a $20 billion industry and some project that brain wearables in particular will be a $12.22 billion industry by 2021 (BCC Research, 2019). Important questions arise from this popularization of neurotechnologies, including safety and efficacy in general and for vulnerable populations such as children and people with disabilities, the management of public expectations, and the privacy and integrity of personal data that may be collected.

The impact of this commercial involvement is also felt at the investigational level, where commercial interests face incentive structures and constraints that differ from those that apply in the context of university-based and government-funded work. Basic and clinical research, as well as the emerging treatment options for brain diseases derived from these efforts, rely more and more on data- and device-driven methods. As indicated in the preceding, the rise of big data, advanced machine learning (particularly artificial neural networks for deep learning), and devices for recording from or intervening in the brain, in turn, increasingly requires the engagement of specialists from fields such as computer science, data science, AI, engineering, and related disciplines. These researchers are also highly coveted by the private sector, particularly the financial sector and large information technology companies. In this competition, publicly sponsored research institutions and even public–private institutions find it challenging to compete with the incentives and financial means of private sector companies and military neurotech programs (Clark 2017; Miranda et al. 2015; Regalado 2017; Statt 2017; Strickland 2017). This brain drain of talented researchers comes with a substantial shift in the way in that choices are made about how research institutions pursue and prioritize applications, research areas, and use cases.

Furthermore, the same big technology companies that spend substantial resources to recruit specialists from academic science also invest in shaping the ethical and societal discourse around emerging (neuro)technologies through advocacy initiatives (e.g., the Partnership for AI) and by sponsoring chairs and departments at universities and research institutions (Kahn 2019).

Apart from the economically driven pressures and changes, the area of military neurotechnology continues to pose significant ethical, legal, and social challenges, such as the problem of regulating the dual-use aspect of neurotechnology and AI (Ienca, Jotterand, and Elger 2018), the possibility of a neurotechnological arms race, and the human rights questions regarding the legitimacy of what Noll (Noll 2014) has termed "neuroweapons" for lethal and nonlethal warfare or policing.

CONCLUSION AND OUTLOOK

Technology is rapidly advancing, knowledge is increasing, research programs are growing, and applications for neurological interventions are proliferating. This expansion has implications for both the near- and the mid-term future. As the scientific understanding of both the healthy and disordered brain grows deeper over time, technological devices and research methods, as well as the innovation dynamics of commercial neurotechnologies, become more complex. This scientific, technological, social, and global expansion requires a highly coordinated, open, inclusive, cross-cultural, interdisciplinary, and flexible response from the global neuroethics community. Neuroethics as a field should continue to expand its conceptual toolbox by incorporating analytic instruments and empirical approaches from other fields, such as science and technology studies, human–machine interaction studies, design thinking, and others. This will enable neuroethics to seamlessly adapt to the rapid technological change, transdisciplinary requirements, and emerging sociotechnological challenges. We hope that such active effort will expedite the already increasing professionalization and academic opportunities for neuroethicists from all professional and academic backgrounds to work together to promote human flourishing and diversity of brains and minds.

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REFERENCES

Ad Hoc Committee of the Harvard Medical School. 1968. A definition of irreversible coma. *JAMA* 205(6): 337–340.

Amadio, J., G.-Q. Bi, P. F. Boshears, A. Carter, A. Devor, K. Doya, H. Garden, J. Illes, L. S. M. Johnson, and L. Jorgenson. 2018. Neuroethics questions to guide ethical research in the international brain initiatives. *Neuron* 100(1): 19–36. doi: 10.1016/j.neuron.2018.09.021.

Anderson, J. A., M. Eijkholt, and J. Illes. 2013. Ethical reproducibility: Towards transparent reporting in biomedical research. *Nature Methods* 10(9): 843. doi: 10.1038/nmeth.2564.

Bailey, J., and S. Pereira. 2018. Advances in neuroscience imply that harmful experiments in dogs are unethical. *Journal of Medical Ethics* 44 (1): 47–52. doi: 10.1136/medethics-2016-103630.

Barlyn, S. 2018. Strap on the fitbit: John Hancock to sell only interactive life… *Reuters*, September 19. Available at: https://www.reuters.com/article/us-manulife-financi-john-hancock-life-ins-idUSKCN1LZ1WL.

BCC Research. 2019. Wearable medical devices: Technologies and global markets. February. Available at: https://www.researchandmarkets.com/reports/4755813/wearable-medical-devices-technologies-and-global

Bittlinger, M. 2017. The patient's voice in DBS research: Advancing the discussion through methodological rigor. *AJOB Neuroscience* 8(2): 118–120. doi: 10.1080/21507740.2017.1320323.

Button, K. S., J. P. A. Ioannidis, C. Mokrysz, B. A. Nosek, J. Flint, E. S. J. Robinson, and M. R. Munafò. 2013. Power failure: Why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience* 14(5): 365–376. doi: 10.1038/nrn3475.

Cabrera, L. Y., M. Bittlinger, H. Lou, S. Müller, and J. Illes. 2018. The Re-emergence of psychiatric neurosurgery: Insights from a cross-national study of newspaper and magazine coverage. *Acta Neurochirurgica* 160(3): 625–635. doi: 10.1007/s00701-017-3428-1.

Cabrera, L. Y., J., Tesluk, M. Chakraborti, R. Matthews, and J. Illes. 2016. Brain matters: From environmental ethics to environmental neuroethics. *Environmental Health* 15(1): 20.

Christen, M., C. Ineichen, M. Bittlinger, H.-W. Bothe, and S. Müller. 2014. Ethical focal points in the international practice of deep brain stimulation. *AJOB Neuroscience* 5(4): 65–80. doi: 10.1080/21507740.2014.939380.

Clark, L. 2017. Elon Musk reveals more about his plan to merge man and machine with neuralink. *Wired UK*, April 21. https://www.wired.co.uk/article/elon-musk-neuralink.

Coates McCall, I., H. Lou, C. Lau, and J. Illes. 2019. Owning ethical innovation: Claims about commercial brain wearable technologies. *Neuron* 102(4): 728–731.

Collins, P. Y., V. Patel, S. S. Joestl, D. March, T. R. Insel, A. S. Daar, I. A. Bordin, et al. 2011. Grand challenges in global mental health. *Nature* 475 (July): 27–30. doi: 10.1038/475027a.

Eckhouse, L., K. Lum, C. Conti-Cook, and J. Ciccolini. 2019. Layers of bias: A unified approach for understanding problems with risk assessment. *Criminal Justice and Behavior* 46(2): 185–209. doi: 10.1177/0093854818811379.

Eklund, A., T. E. Nichols, and H. Knutsson. 2016. Cluster failure: Why FMRI inferences for spatial extent have inflated false-positive rates. *Proceedings of the National Academy of Sciences* 113(28): 7900–7905. doi: 10.1073/pnas.1602413113.

Farahany, N. A., H. T. Greely, S. Hyman, C. Koch, C. Grady, S. P. Pașca, N. Sestan, P. Arlotta, J. L. Bernat, J. Ting., et al. 2018. The ethics of experimenting with human brain tissue. *Nature* 556(7702): 429. doi: 10.1038/d41586-018-04813-x.

Feigin, V. L., A. A. Abajobir, K. H. Abate, F. Abd-Allah, A. M. Abdulle, S. F. Abera, G. Y. Abyu, M. B. Ahmed, A. N. Aichour, I. Aichour, et al. 2017. Global, regional, and national burden of neurological disorders during 1990–2015: A systematic analysis for the global burden of disease study 2015. *The Lancet Neurology* 16(11): 877–897. doi: 10.1016/S1474-4422(17)30299-5.

Global Neuroethics Summit Delegates. 2018. Neuroethics questions to guide ethical research in the international brain initiatives. *Neuron* 100(1): 19–36.

Griffiths, M. 2019. How many stars is a smile worth? The social cost of emotional labour. *The Guardian*, February 3. Available at: https://www.theguardian.com/media/2019/feb/04/how-many-stars-is-a-smile-worth-the-social-cost-of-emotional-labour.

Grillner, S., N. Ip, C. Koch, W. Koroshetz, H. Okano, M. Polachek, M.-m. Poo, and T. J. Sejnowski. 2016. Worldwide initiatives to advance brain research. *Nature Neuroscience* 19 (9): 1118–1122. doi: 10.1038/nn.4371.

Grossman, N., D. Bono, N. Dedic, S. B. Kodandaramaiah, A. Rudenko, H.-J. Suk, A. M. Cassara, et al. 2017. Noninvasive Deep Brain Stimulation via Temporally Interfering Electric Fields. *Cell* 169 (6): 1029–1041.e16. doi: 10.1016/j.cell.2017.05.024.

Hanna, F., C. Barbui, T. Dua, A. Lora, M. van Regteren Altena, and S. Saxena. 2018. Global mental health: How are we doing? *World Psychiatry: Official Journal of the World Psychiatric Association (WPA)* 17(3): 367doi: 10.1002/wps.20572.

Ienca, M., P. Haselager, and E. J. Emanuel. 2018. Brain leaks and consumer neurotechnology. *Nature Biotechnology* 36(9): 805–810. doi: 10.1038/nbt.4240.

Ienca, M., F. Jotterand, and B. S. Elger. 2018. From healthcare to warfare and reverse: How should we regulate dual-use neurotechnology? *Neuron* 97(2): 269–274. doi: 10.1016/j.neuron.2017.12.017.

Illes, J., S. Weiss, J. Bains, J. A. Chandler, P. Conrod, Y. De Koninck, L. K. Fellows, D. Groetzinger, E. Racine, J. M. Robillard, et al. 2019. A neuroethics backbone for the evolving Canadian brain research strategy. *Neuron* 101 (3): 370–374. doi: 10.1016/j.neuron.2018.12.021.

Kahn, J. 2019. Facebook endows AI ethics institute at German University TUM - Bloomberg. *Bloomberg*. January 20. Available at: https://www.bloomberg.com/news/articles/2019-01-20/facebook-endows-ai-ethics-institute-at-german-university-tum.

Kandel, E. R., H. Markram, P. M. Matthews, R. Yuste, and C. Koch. 2013. Neuroscience thinks big (and collaboratively). *Nature Reviews Neuroscience* 14(9): 659. doi: 10.1038/nrn3578.

Kellmeyer, P. 2017. Ethical and legal implications of the methodological crisis in neuroimaging. *Cambridge Quarterly of Healthcare Ethics* 26(4): 530–554. doi: 10.1017/S096318011700007X.

Kellmeyer, P. 2018. Big brain data: On the responsible use of brain data from clinical and consumer-directed neurotechnological devices. *Neuroethics*. doi: 10.1007/s12152-018-9371-x.

Kreitmair, K. V., M. K. Cho, and D. C. Magnus. 2017. Consent and engagement, security, and authentic living using wearable and mobile health technology. *Nature Biotechnology* 35(7): 617–620. doi: 10.1038/nbt.3887.

Lavazza, A., and M. Massimini. 2018. Cerebral organoids: Ethical issues and consciousness assessment. *Journal of Medical Ethics* 44(9): 606–610. doi: 10.1136/medethics-2017-104555.

Lozano, A. M. 2017. Waving hello to noninvasive deep-brain stimulation. *New England Journal of Medicine* 377 (11): 1096–1098. doi: 10.1056/NEJMcibr1707165.

Martinez-Martin, N., T. R. Insel, P. Dagum, H. T. Greely, and M. K. Cho. 2018. Data mining for health: Staking out the ethical territory of digital phenotyping. *npj Digital Medicine* 1(1): 68. doi: 10.1038/s41746-018-0075-8.

Miranda, R. A., W. D. Casebeer, A. M. Hein, J. W. Judy, E. P. Krotkov, T. L. Laabs, J. E. Manzo, et al. 2015. DARPA-funded efforts in the development of novel brain–computer interface technologies. *Journal of Neuroscience Methods, Brain Computer Interfaces; Tribute to Greg A. Gerhardt* 244: 52–67. doi: 10.1016/j.jneumeth.2014.07.019.

Mordre, M.,. B. Groholt, E. Kjelsberg, B. Sandstad, and A. M. Myhre. 2011. The impact of ADHD and conduct disorder in childhood on adult delinquency: A 30 years follow-up study using official crime records. *BMC Psychiatry* 11(1): 57doi: 10.1186/1471-244X-11-57.

Munafò, M. R., B. A. Nosek, D. V. M. Bishop, K. S. Button, C. D. Chambers, N. Percie Du Sert, U. Simonsohn, E.-J. Wagenmakers, J. J. War, and J. P. A. Ioannidis. 2017. A manifesto for reproducible science. *Nature Human Behaviour* 1(1).

Noll, G. 2014. Weaponising neurotechnology: International humanitarian law and the loss of language. *London Review of International Law* 2(2): 201–231. doi: 10.1093/lril/lru009.

Nuffield Council on Bioethics. 2018. Bioethics briefing note: Artificial intelligence (AI) in healthcare and research. May. Available at: http://nuffieldbioethics.org/wp-content/uploads/Artificial-Intelligence-AI-in-healthcare-and-research.pdf

Nuttin, B., H. Wu, H. Mayberg, M. Hariz, L. Gabriëls, T. Galert, R. Merkel, C. Kubu, O. Vilela-Filho, K. Matthews, et al. 2014. Consensus on guidelines for stereotactic neurosurgery for psychiatric disorders. Journal *of Neurology, Neurosurgery, and Psychiatry* 85(9): 1003–1008. doi: 10.1136/jnnp-2013-306580.

Paul, D. 2017. Your own pacemaker can now testify against you in court. *Wired*, July 29. Available at: https://www.wired.com/story/your-own-pacemaker-can-now-testify-against-you-in-court/.

Poldrack, R. A., J. Monahan, P. B. Imrey, V. Reyna, M. E. Raichle, D. Faigman, and J. W. Buckholtz. 2018. Predicting violent behavior: What can neuroscience add? *Trends in Cognitive Sciences* 22(2): 111–123. doi: 10.1016/j.tics.2017.11.003.

Psychosurgery Review Board. 2012. 2011/2012 annual report. Melbourne. Available at: https://www.parliament.vic.gov.au/file_uploads/VicPsychosurgeryReviewBoard2011-12_T9TFYnJy.pdf.

Regalado, A. 2017. Google's health-care mega-project will track 10,000 Americans. *MIT Technology Review*. Avaiable at: https://www.technologyreview.com/s/604224/googles-massive-health-study-seeks-10000-volunteers-to-give-up-their-medical-secrets/.

Rong, G., S. R. Corrie, and H. A. Clark. 2017. In vivo biosensing: progress and perspectives. *ACS Sensors* 2(3): 327–338. doi: 10.1021/acssensors.6b00834.

Schumann, G., V. Benegal, C. Yu, S. Tao, T. Jernigan, A. Heinz, R. Araya, L. Yu, and V. Calhoun. 2019. Precision medicine and global mental health. *The Lancet Global Health* 7(1): e32. doi: 10.1016/S2214-109X(18)30406-6.

Spranger, T. M. 2012. Neurosciences and the law: An introduction. In *International neurolaw*, ed. by T. M. Spranger, 1–10. Berlin Heidelberg: Springer.

Statt, N. 2017. Kernel is trying to hack the human brain — but neuroscience has a long way to go. *The Verge*. February 22. Available at: http://www.theverge.com/2017/2/22/14631122/kernel-neuroscience-bryan-johnson-human-intelligence-ai-startup.

Strickland, E. 2017. Facebook announces "Typing-by-Brain" Project'. *IEEE Spectrum: Technology, Engineering, and Science News*. April 20. Available at: https://spectrum.ieee.org/the-human-os/biomedical/bionics/facebook-announces-typing-by-brain-project.

Tomlinson, M., I. Rudan, S. Saxena, L. Swartz, A. C. Tsai, and V. Patel. 2009. Setting priorities for global mental health research. *Bulletin of the World Health Organization* 87 (June): 438–446. doi: 10.2471/BLT.08.054353.

Wallach, W., and Colin Allen. 2008. *Moral machines: Teaching robots right from wrong*. New York, NY: Oxford University Press.

Wexler, A. 2015. The practices of do-it-yourself brain stimulation: Implications for ethical considerations and regulatory proposals. *Journal of Medical Ethics*. Available at: https://doi.org/10.1136/medethics-2015-102704.

Wexler, A. 2017. Who uses direct-to-consumer brain stimulation products, and why? A study of home users of TDCS devices. *Journal of Cognitive Enhancement* 1–21. Available at: https://doi.org/10.1007/s41465-017-0062-z.

WHO. 2005. Ecosystems and human well-being: Health synthesis. A report of the millennium ecosystem assessment. Geneva, Switzerland. Availble at: https://www.who.int/globalchange/publications/ecosystems05/en/.

Wind, J. J., and D. E. Anderson. 2008. From prefrontal leukotomy to deep brain stimulation: The historical transformation of psychosurgery and the emergence of neuroethics. Neurosurgical *Focus* 117(1): E10. doi: 10.3171/FOC/2008/25/7/E10.

Yuste, R., S. Goering, B. A. y Arcas, G. Bi, J. M. Carmena, A. Carter, J. J. Fins, P. Friesen, J. Gallant, J. E. Huggins, et al. 2017. Four ethical priorities for neurotechnologies and AI. *Nature* 551(7679): 159. doi: 10.1038/551159a.