Neuron

Perspective

Building a culture of responsible neurotech: Neuroethics as socio-technical challenges

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SUMMARY

Scientists around the globe are joining the race to achieve engineering feats to read, write, modulate, and interface with the human brain in a broadening continuum of invasive to non-invasive ways. The expansive implications of neurotechnology for our conception of health, mind, decision-making, and behavior has raised social and ethical considerations that are inextricable from neurotechnological progress. We propose "socio-technical" challenges as a framing to integrate neuroethics into the engineering process. Intentionally aligning societal and engineering goals within this framework offers a way to maximize the positive impact of next-generation neurotechnologies on society.

INTRODUCTION

Advances in neuroscience and neurotechnology are expanding society's ability to improve human health and performance. Fueled by recent investments from government and private industry, the tools for measuring and modulating brain activity are rapidly gaining sophistication (BCI, 2021).

For people suffering from brain-related disease and injury, developing new neurotechnologies that improve their quality of lives is a moral imperative. In order for these technologies to truly deliver improved quality of life on a day to day basis, these new neurotechnologies will need to be safe, easy to use, and successful at meeting performance criteria that are co-created with end users. In recognition of these imperatives, governments around the globe, non-profit groups, and private industry have increased their support of neurotechnology development. The European Union and United States launched major funding efforts in 2013, and more have proliferated in several countries including Japan, Korea, and China (GNS Delegates et al., 2018). The development of new tools has fueled significant private sector investment to translate these tools into therapeutic and consumer products. Major technology companies including Facebook/Meta and Google are investigating brain-compute -interfaces, joining a growing group of neurotech startup companies. Given the ethical imperative to further develop neurotechnology, it should be no surprise that the prominent motivation of many neuroscientists and engineers is to reduce pain and suffering by improved interventions and a better understanding of the brain itself (Moss et al., 2021).

In addition, brain technologies bring the potential to reveal significant insights into the most defining features of the human experience such as decision-making and free will, cognitive experience, emotion, and one's identity. The promise of being able to both read and write into the brain raises significant neuroethics concerns (i.e., philosophical, legal, and social implications of neuroscience) making the neuroethical implications for society just as important to consider as the ethical imperative to do neuroengineering work.

Traditionally, engineers aim to achieve these goals by improving technological performance such as making technologies less invasive, higher resolution, more adaptive, or longer lasting. That said, there may be another opportunity to address these problems more holistically. Indeed, many engineers are motivated to create solutions that improve society but a predominant perception is that neuroethics is equivalent to compliance. Such a view frames neuroethics in a counterproductive light for innovation because neuroethics may be seen as inhibiting the ability to rapidly innovate and compete in fast-paced commercial sectors. Instead, we see an opportunity to recognize that neuroethics is a way to enhance creative problem solving with foresight and holistically address the translation of technology into society. Indeed, engaging in neuroethics as part of the problem solving toolkit can enhance imagination and creativity (Moss et al., 2021). We want to highlight that many of the goals of neuroethicists and neuroengineers are shared: they each aim to improve society. Thus we see an opportunity to reframe this relationship as a constructive collaboration.

To foster a collaborative relationship between neuroethicists and engineers we argue for elevating ''socio-technical challenges'' to funding priorities and ''grand challenges.'' This approach could align the incentives of both engineers and ethicists toward a future of responsible, fair, safe, and empowering neurotechnologies.

The intent of this article is to propose a call to action for funders, policymakers, and leaders to help shape the neurotech research agenda to identify and reward engineering challenges that also address issues of societal importance.

For example, making lower cost neurotechnologies is a common goal for engineers, but it also has an important social component. Lower cost technologies could expand access to new therapies to under-resourced groups, which is a known societal issue facing the clinical rollout of biomedical innovations (Gupta, 2021). Similarly, developing technologies with broad software and hardware support would allow multiple companies to support the same piece of neurotechnology so that people could continue to benefit from their device even if the original manufacturer goes out of business. These examples are of engineering challenges that also have important societal ramifications, making them examples of what we will refer to as ''socio-technical challenges.'' How can we better incentivize engineers and scientists to prioritize these engineering challenges that also have a social and ethical impact? What are the possible levers for systems change?

This can be done by fostering ethical imagination while driving innovative engineering. Indeed, a culture of collaboration between the engineers and ethicists may be our best chance for ensuring that the inevitable future of neurotechnology develops in a way that chooses responsible social impact from its inception.

TENSIONS BETWEEN ETHICISTS AND SCIENTISTS/ ENGINEERS

While framing engineering challenges as ''socio-technical'' challenges may seem natural, there are often social and cultural barriers that make it difficult to integrate new ethical considerations into the engineering workflow. Proposals have also been put forward to integrate ethics into other fields of engineering such as with nanotechnology and the growing movement toward ethically aligned design in the AI community (IEEE, 2019). Prominent History of Science and Science and Technology scholars have critiqued the epistemological hierarchy of ''science'' over the ''humanities'' which can also cause discord in fruitful collaborations (Callard and Fitzgerald, 2015; Vidal, 2009). The challenge has been to put science and ethics at equal footing in an aligned effort toward societally impactful neuroscience. Part of that equal footing will require an alignment of a shared footing ethos in the development incentive (and funding) structures.

Fundamental misunderstanding of the value proposition of ethics for neuroscientists is also harmed by standard practices of ethics training. For example, a legacy of click-based compliance-oriented ethics training so familiar to those who have been required to obtain responsible conduct of research (RCR) training may have dimmed the enthusiasm of many engineers for ethics tools and thinking (Goering and Klein, 2020).

This cultural divide may also reflect antiquated views of neuroethics. Just as neurotechnologies have developed cutting edge methods to interface with the brain and body, neuroethics has developed alongside these advances offering new tools and frameworks to consider the oft-missing humanistic angles and implications of neuro-engineering feats. When deployed proactively, neuroethics can even advance and accelerate neurotechnology development by offering more imaginative design, and prepare technologies for positive trajectories for use in society. Many consumers, particularly Millennials and GenZers are also socially conscious and want to support products and companies that take a responsible approach toward technology development (The Deloitte Global, Millennial and Gen Z Survey, 2021; Francis and Hoefel, 2018). In other words, practicing good neuroethics can provide financial value to commercial neurotech by helping businesses build trust with their customers, who could be patients, researchers, other businesses, or consumers. (Moss et al., 2021; Moss and Rommelfanger, 2021). To be clear, this is not to suggest that the practice of ethics be purely instrumental or a superficial marketing endeavor for businesses. Instead, the intent is to acknowledge that ethics, raising issues and having a healthy critical mindset to watch for pitfalls of misuse and abuse can fit into a sustainable business strategy that generates social good.

ETHICAL CONCERNS IN ENGINEERING

Recent working groups composed of neuroscientists, ethicists, and cultural scholars have identified five neuroethics questions for neuroscientists (GNS Delegates et al., 2018). However, these questions may not be best articulated for neuroengineers. As a result, several dedicated groups are building neuroethics frameworks for engineers (IEEE Neuroethics Framework, 2021). Although many of the ethical questions and concerns are similar for scientists and engineers, the context can differ. Although there are no definite lines that can be easily drawn between the fields, for many scientists the main work product is knowledge, while for many engineers the main work product is technology (Pinelli, 2001). These distinctions in orientation create a different relationship with the public. The general public may rarely become a direct consumer of literature in academic journals (the primary output of scientific work) but are often direct consumers of technology. As a result, the context for neuroethics in neurotechnologies is perhaps best framed by discussing the direct effects of technology on the end-user groups. Even so, gaps remain in adequately addressing end-user concerns and input. For example, a recent IEEE BCI Standards landscape called for deeper engagement with the end users in BCI design and standards-making (Neurotechnologies for brain-machine interfacing, 2020). Overall, this gap presents an opportunity for reflection and robust user-centric practices and reveals what a socio-technical engineering ethos would offer. Next, we highlight five ethical dimensions that are critical pieces of a socio-technical framework.

Access

A critical piece of the ethical imperative of neuroscience is to broadly share the benefits of neurotechnological advances. Access is a complex web of societal factors such as regulatory safety, clinical adoption, or financial feasibility, which is often ironically hindered by tools ultimately designed to protect people. For example, for safety reasons, vulnerable groups, such as children, are often excluded from studies and therefore also from the future benefits of those technologies. Arguably many neurotechnologies are developed under a traditional medical model and therefore the point of delivery is within a complex healthcare system (Judah et al., 2021). Regulatory entities and clinicians that control access to treatments often have limited information on the perspectives of people with disabilities who may view the risk benefit trade-off differently than clinicians and regulatory entities (Mühlbacher et al., 2016).

Safety and well-being

Other relevant concerns for neuroengineers are around safety and well-being. Post-trial responsibilities for invasive neural implants have left participants to personally cope with maintaining or even finding alternatives to devices once the study has ended (Hendriks et al., 2019). Financial incentives may not be well-aligned with the needs of society or even with the goals of founders of neurotechnology. Even early design concepts may be poorly positioned for commercialization or intentionally created to achieve intermediate milestones, while pioneering trial participants are left with the scars of obsolete technology.

Dual use

Dual-use concerns, often framed as technologies repurposed for military or national security applications, have been raised in several prominent reports outlining ethical tension and guidelines around incorporating neuroscience in the war theater, particularly around incapacitation. Or, in the case of the EU Human Brain Project, scientists are urged explicitly not to engage in science that will "threaten peace, security, or health" (Brain Waves Module 3: Neuroscience, conflict and security, 2012; Opinion on 'Responsible Dual Use' 2018). Another form of dual use includes the not-so-bright line between therapy and enhancement that neurotechnology could offer (and many neuro-entrepreneurs hope to offer). Enhancement raises questions about who would have access to "enhancing" technologies and would such "enhancements" further widen the gap of inequities (GNS Delegates, et al., 2018; Ray, 2016). Ethical issues around human enhancement and cognitive enhancement particularly have been one might argue exhaustively discussed, without clear resolution (Allen and Strand, 2015). To be clear, reappropriating technologies for an application they were not initially designed for (dual use) can have both positive and negative outcomes for society. Neurotechnology continues to advance and new sensing technologies designed for military or enhancement may offer predictive insights on risks of developing a variety of brain disorders and shift intervention toward "treating healthy" individuals earlier (Ahlgrim et al., 2019). Technologies that are initially developed for national security can also find their ways into empowering civilians. Examples include the internet, microwave ovens, and GPS.

Bias

Scientists are also becoming increasingly aware of the impact of bias in neurotechnology development, discovery, and interpretations of results. Neurotechnology can be an important tool in better understanding aspects of our brains that were previously unknown to us, but the enthusiasm to gain this knowledge can dwarf important considerations of the limitations of analyzing datasets from homogeneous populations and training samples. In any scientific field, data are often analyzed across variables of socially constructed identities (e.g., gender and race) that if not interpreted carefully can serve to reify existing norms of discrimination. This is not to suggest that efforts in research oriented around exploring sex as a biological variable are not laudable or legitimate (Clayton, 2018). Instead, we recognize the need to enhance science through a more nuanced and intentional use of terms and variables (Borrell et al., 2021). Another kind of bias may be around approaches to new interventions. Both research and in turn, clinical approaches might center more on convenience and economic priorities, which may not incentivize development of the most innovative technologies (i.e., over upgrading existing technology) with the potential to provide the best therapies and/or greatest access.

Privacy

The last grouping of ethical concerns emerges from broad conversation around data privacy. Enormous amounts of data are being collected on everyone every day from a variety of passive and active sensing devices including commercial and clinical-grade neural technologies (Insel, 2017; Zook et al., 2017). For many participants in studies or even users who purchase devices, it may be unclear exactly how that data could be used now, or especially in the future. Further, such data may have value in the future that it does not currently have due to advances in understanding of the brain and how to analyze across larger, combined datasets. Technologies particularly oriented around predicting future brain health could be used for discriminatory purposes, such as with health and life insurance or lead to stigmatizing groups of individuals (Ahlgrim et al., 2019).

PUTTING ETHICS AND ENGINEERING ON EQUAL FOOTING: USING SOCIO-TECHNICAL CHALLENGES TO DRIVE ETHICALLY ALIGNED NEUROTECHNOLOGY DEVELOPMENT

Currently, there are over twenty "sets" of neuroethics guidelines (see Institute of Neuroethics: Guidance, 2021). There is no shortage of recommendations, but the challenge of implementation is a significant hurdle. Many engineers remain unaware of these resources, but, why is that the case?

We suspect that part of the issue is the unclear value proposition for neuroengineers. Engineers have a set of common-sense incentives. These include an intellectual drive to identify elegant and clever solutions to engineering challenges, a desire to overcome societal problems with engineering solutions, and a practical need for finding funding (regardless of the public or private sector context).

One way to drive the framing of neuroethics for the neural engineering community might be to align existing ethical concerns with incentives for engineers. To reframe neuroethical issues as engineering challenges we can acknowledge that many engineering challenges naturally have social implications, making it possible to use these themes as levers to push neurotechnologies toward more responsible development. What if ethics challenges could be re-imagined as engineering challenges as well? Examples of this are already emerging such as wireless technology and privacy by design.

EXAMPLE SOCIO-TECHNICAL CHALLENGES

It is possible to reframe several ongoing efforts within the scientific and engineering communities as socio-technical challenges. For example, many neuroengineers are working to make smaller, less invasive neurotechnologies. Replacing the existing technologies that are large and require invasive procedures for implantation will reduce the real and perceived risks for the people in need of the technology. Thus, this engineering effort touches on the neuroethical issue of access—who can benefit from these technologies with the current risk profile, and what kinds of expanded access could be achieved if these technologies were safer and less invasive? Even for some existing neurotechnologies that are more accessible, they may suffer from lack of long-term safety and use guidelines. The safety profile of many commercially available non-invasive devices such as TENS and tES are not well established under the at-home conditions where they are often used (Antal et al., 2017). Many advanced neuroprosthetics are still not accessible due, in part, to the high costs associated with manufacturing, deployment, and maintenance. Thus, making technologies that are low cost is also an engineering challenge that will improve access to less-resourced and more diverse communities. Of note is that the cost of implantation can also add higher legal, insurance, and documentation costs related to risks associated with deployment.

There are also engineering challenges related to bias and privacy. Just as artificial intelligence algorithms have been shown to have bias that was integrated as the result of choices made by software engineers (West et al., 2019), there is a danger for bias to be integrated into neurotechnology by similar engineering decisions even when there is no intentional bias on the part of the developers. Thus, consciously developing unbiased neurotechnologies can be considered a socio-technical engineering challenge. For example, existing non-invasive brain monitoring technologies like EEG and fNIRS show reduced efficacy for people with dark skin and thick curly hair (Fau et al., 2020), but researchers are working to overcome this challenge by creating engineering platforms that perform equally well for all hair and skin types. Similarly, engineers can help ensure privacy for neural data by developing secure interfaces that have cross-platform compatibility. In this way technologies may remain supported and protected even if a company with a proprietary software interface goes out of business. Understanding early in the design process that we can engineer solutions to ensure that sensitive neural data are protected can inspire engineers to make design choices that improve the privacy of any neural-data-recording technology. For example, engineers could improve privacy by focusing efforts on recording systems that use wireless technologies that are very short-range communication such as near-field inductive coupling, magnetoelectrics, ultrasound, or body channel communication (Singer and Robinson, 2021). These short-range communication protocols could be more easily secured.

ESTABLISHING A CULTURE OF SOCIO-TECHNICAL ENGINEERING

How might we establish a culture where neuroethicists and engineers are aligned in solving socio-technical challenges? We argue that we are most likely to succeed if we work within the existing incentive structures of the two communities. For example, within our group of authors we identified that engineers driven by intellectual curiosity to create elegant solutions for critical societal challenges are often constrained by available funding. Thus, funding agencies can play a major role in supporting design efforts aimed at socio-technical problems, by releasing special calls and "grand challenges with a core neuroethics framework" awards for these types of projects. We may also see leadership from private-sector-led grants. For example, Facebook has recently put forward a "Request for proposals on engineering approaches to responsible neural interface design." (Request for proposals on engineering approaches to responsible neural interface design, 2021)

There are also several levers to push neuroengineering work toward socio-technical objectives. These levers could include not just physical resources but education and training in ethics to raise awareness as has been suggested by many neuroethicists (Cabrera and Bluhm, 2020; Goering and Klein, 2020; Rommelfanger, 2020; Wexler, 2020). New resources are being developed by engineering societies like IEEE Brain.

Innovation in data-sharing platforms could offer better and more secure ways to share data—ranging from material composition and fabrication processes to neural data and cognitive outcomes obtained using the devices. A socio-technical challenge to orient around could include how to ensure neurotechnologies make use of neural data without rendering users vulnerable to violations of their privacy.

Finally, critical to all these considerations and the development of a robust socio-technical framework would be to engage in mutual exchange across stakeholders deploying goals, methods, and strategies of public engagement. To date, a number of stakeholders have been missing from conversations around the social and ethical dimensions of neuroscience from lived experience advocates and end users to payers. Engaging a broader stakeholder group could enhance the identification and resolution of emerging ethical tensions in neural engineering. This could include deliberative techniques with relevant stakeholders where all participants are on equal footing in mutual dialogue and exchange, community based participatory research methods, and workshops on neuroscience diplomacy. Key stakeholders missing from many conversations include current and future end users of technologies and their care-giving networks.

CALL TO ACTION AND CLOSING COMMENTS

In this paper, we propose that framing neuroethical priorities as "socio-technical" engineering challenges will guide neurotechnology toward socially responsible development and use. As an immediate next step, we invite scientists and clinicians to participate in deeper community engagement to generate more specific lists of socio-technical challenges that will help align neurotechnology development with neuroethics, and to better develop the levers to prioritize this work in the academic and private sectors. Specifically, we suggest workshops to gather input from a diverse set of stakeholders and empirical work that will provide data to guide the development of future socio-technical research efforts. We see particular opportunities, also informed by the IEEE standards road map, for exploring brain computer interfaces and finding ways to better elevate end-user voices. The input of end users and their caregivers should be meaningfully incorporated into the design and dissemination choices made with neuroengineering discoveries. We invite community engagement around creating an actionable strategy with clear incentives to implement that strategy. Finally, we believe in addition to scientists and end users, funders from governments to private foundations to investors must play a critical role in enabling and incentivizing ethically minded work.

Longer term efforts will also be needed to drive a culture change. Example actions include developing indicators of social impact in partnerships with policy makers, foundations, philanthropists, current and future end users, patients and lived experience advocates. One potential opportunity could be integrating into existing impact measurement structures for investors such as the environmental, social, and governance rubrics developed by the UN (Our Common Agenda, 2021) with existing neuroethics legal instruments such as the Organization for Economic Cooperation and Development's Recommendation on Responsible Innovation in Neurotechnology (OECD, 2019). This is a project currently in development in collaboration with the Institute of Neuroethics of which authors J.R. and K.S.R. are involved.

These impact measures could be used to evaluate the merit of proposed research projects and commercialization plans and to measure their success. New research funding opportunities could be specifically designed to equally weigh technological merit and social impact in their evaluation criteria.

Ideally, this culture shift would result in neuroethics being viewed by engineers less as a compliance obligation and more expansively as a source of important and exciting engineering challenges. To achieve this shift will require efforts from multiple elements of the scientific community. Student and faculty education could include more community engagement that will help engineers identify critical societal problems, personally engage with the stakeholders, and dream up engineering solutions. The media could highlight more examples of how engineers have used technology to solve societal problems and examples of existing societal problems where engineering solutions remain a work in progress. This coverage could raise awareness for some of the opportunities that engineers have to make a positive societal impact. Funders in the government and philanthropic sectors could develop programs that adopt a similar framing and offer support for researchers using engineering solutions to solve societal challenges in a responsible way. These efforts could lead to lasting change if corporations can adopt these socio-technical solutions without having to invest heavily into ethically aligned research and development projects that may not directly increase their profit margin. Additional work to develop incentives such as ESGs for neurotechnology may make it possible to directly link social responsibility to profitability (Smith et al, 2021). Together these efforts may help guide us toward a future where next-generation neuroengineers and scientists achieve both transformative technological advances and solutions to critical societal challenges. A successful shift toward solving these socio-technical challenges could maximize the positive impact of next-generation neurotechnologies on society.

DECLARATION OF INTERESTS

K.S.R. offers consultation for nonprofits, policy institutions, NGOs, and neurotechnology companies. A.E. leads all Sevo-related work at CMU and Precision Neuroscopics and offers paid talks related to this technology. R.W.P. receives royalties on patents for her AI-related and wearables inventions owned by MIT and is a co-founder and shareholder of Empatica, Inc., where she serves as Chairman of the Board and consults part-time as Chief Scientist. She is also a shareholder at Smart Eye AB, which acquired Affectiva, a company she co-founded. At MIT, her lab's research receives funding from the NIH via Massachusetts General Hospital Depression Research Clinic and from a consortium of over fifty companies listed at https://www.media.mit.edu/posts/member-companies. She receives speaker fees through Stern Strategy. These relationships present no conflict of interest at the time of this paper submission.

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