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Grey Matters – exploring technologists perceptions of dual-use potentiality in emerging neurotechnology applications

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Abstract

This paper reports on a pilot study examining perceptions of dual–use among neurotechnologists and neuroethicists. Ten semi-structured interviews were carried out with participants from established universities in the United States, the United Kingdom and Australia about the risks they saw with the new technology and about who has responsibility for safely developing it. A Grounded Theory approach was utilised to code and develop themes from the data and to lay foundations for analysis. The study found that dual-use was not considered binary, but rather multifaceted and fluid, with the commercialisation and globalisation of the emerging science shifting understandings of 'beneficial' and 'harmful' neurotechnologies and rendering future uses unknowable.

Introduction

Neuroscientific research is generally produced under the maxim of non-maleficence, promoting beneficial applications for its future users. However, it is near impossible to guarantee that no harm will result from neuroscientific innovations and their potential alternate or unintended uses. [1] While emerging neurotechnology applications are continually expanding, in this paper we limit the term 'neurotechnology' to techniques that are encompassed to specifically investigate, emulate or intervene the brain. This includes brain-inspired 'neural networks' and cognitive computing and robotics; brain-computer interfaces and wearable technologies; neuromorphic computing; and brain stimulator devices. [2-5] While these neurotechnologies have multiple uses, including medical, educational, lifestyle, and defensive uses, we are interested in the arms control concept of 'dual-use,' referring to a technology's or a piece of scientific research's potential to be used for good as well as harm. DU is the unavoidable fact that scientific and medical breakthroughs can be mutually used for purposes unrelated to the goals of the researchers. [6] We agree with others who argue that the term is centred upon moral interpretations of what constitutes good and bad and acknowledge this can be subjective. [7] We are interested to explore what this means in practice, and have undertaken a pilot study examining neurotechnologists' perceptions of dual use potentiality as it applies to their work.

In the case of biological, chemical, and nuclear technologies, international rules exist to ensure these are not used for developing weapons. There are also controls to ensure things like certain electronics, computers, software, sensors, or telecommunications technology are not used in conventional weapons. In all cases, the underlying technologies in question have useful and beneficial purposes. Whilst these regulations consider software and hardware components, they do not consider the specificities of neurotechnologies potential for misuse and are therefore inadequate. Of more relevance are discussions taking place at the United Nations on lethal autonomous weapons systems, particularly around aspects associated with human-machine interactions, the loss of human control, and accountability. While these are limited to weaponry, informal discussions at the United Nations are also examining broader issues around artificial intelligence and militarization, including military decision-making, intelligence-gathering, and command and control systems.

Yet, none of the international regimes or current discussions provide guidance for how people should consider the beneficial and harmful potential that neurotechnology holds, a growing area of research among scholars as militaries begin developing the technology.

The US DoD and its Defence Advanced Research Projects Agency (DARPA) are the global forerunners of developing neuroscientific interventions and technologies aimed at improving military and civilian health. It is possible that neurotechnology development may lead a similar trajectory as the Internet and geographic position system (GPS) which are both examples of technologies that were originally created for military purposes but then went onto to be used to benefit society at large. Research activities that involve possible brain-inspired neurotechnologies for soldier enhancement include intelligence gathering, image analysis, threat and deception detection, manipulation of emotional states, and incapacitation of adversaries. [5] Ambitious projects in these areas have the potential to work as restorative and augmentative applications, but, at the same time, the particular agenda of national militaries and their investments in neurotechnology raise significant social and ethical questions. Neurotechnology becomes problematic when its applications developed by the military for national security purposes also have the potential to disrupt healthcare, communication and other components of the civilian arena. [8] Correspondingly, defence organisations might 'harvest' commercial neurotechnologies and apply them to suit their own purposes. [5] Structured examination of these wider potential implications of emerging neurotechnologies is fundamental to create appropriate policies and oversight systems that ensure sound dual–use assessments whilst allowing for continued scientific flourishing. The study reported in this paper aimed to gather first hand insights into perspectives of neurotechnologists and neuroethicists from a variety backgrounds to explore the risks they saw with the emerging technology and who has responsibility for safely developing it.

Methodology

Eight interviews were carried out with senior neurotechnologists from labs at established universities in the United States, the United Kingdom and Australia. The technologist's disciplinary backgrounds included invasive and non-invasive BCIs, neuromorphic computing, and cognitive robotics, with two participants working on technology to advance the understanding of intelligence and the brain, four working on clinical or therapeutic BCI technology, and two working on direct-to-consumer (DTC) BCI technology that is, neurotechnology applications which are sold directly to a consumer market for personal use without clinical oversight. Two further interviews were conducted with neuroethicists who had extensive scholarship on dual–use. Semi-structured conversational interviews were carried out using a list of predetermined areas. Four core questions were asked, broadly covering:

(1) whether the neurotechnologists felt they ought to monitor dual–use potentiality;
(2) where their funding came from and whether it mattered to them;
(3) whether they perceived a sense of responsibility for the access and future direction of their work; and
(4) what sorts of unintended consequences they have considered for their own work.

The pilot study examined the views of a small sample from particular parts of the neuroscience and technology community with an intention to generate a theory based on the interviewees perceptions that were grounded within the data using a Grounded Theory approach. [9] Interviews were conducted with open ended questions which were then transcribed by the researchers. Each transcript was coded line-by-line and then axial coding was used to develop major categories and bring the data together to develop themes and to lay foundations for analysis. [10] Generalizability was limited in this small-scale project due to time and resources. However, this project's intention was to gather in-depth rich insight that would facilitate further crucial discussion on a topic that will begin to become more prevalent to society at large. Institutional research ethics approval was granted for the study.

Results

(1) Monitoring dual–use potentiality

Six of the technologists were aware of the concept of dual–use, with three stating that misapplication was not a likely possibility for the type of technology they were producing (BCIs, neuromorphic computing, cognitive robotics). Two technologists explained that the technology they had created in the past had gone on to be used for entirely unexpected purposes that would have been impossible to predict and described themselves as being "away from the front line". In juxtaposition to this, two technologists stated they had not come across the concept of dual–use as part of wider socioethical considerations about their technology. Impressions gathered included that dual–use is always possible, that 'reverse' dual–use can occur where defence organisations 'harvest' commercial neurotechnologies and apply them to suit their own purposes, and it was frequently noted throughout the interviews that the terms dual–use and ‘misuse’ or ‘misapplication’ shouldn’t be intertwined due to their differing connotations. Here misuse was understood as being the morally bad use of that technology, whilst misapplication was understood to be the concept of classifying research as ‘of concern’. The technologists who were aware of dual-use described it as “*multifaceted*” and “*fluid*” as case by case basis. These variations in understanding and interpreting dual–use was corroborated by one of the neuroethicists’ opinions that the dual–use label can work as a “*misnomer*”.

(2) Funding sources

Funding was an ongoing consideration for the participants. While most technologists stated that they did not see commercialization of their work as a priority, in order to make their technology more widely accessible, commercialisation was often seen as the only solution. Four technologists explained they had spinout companies using similar technology. The pursuit of private capital led two of the neurotechnologists we spoke with to move to Silicon Valley in California, a place where, as one of them said, *“We don’t even have to explain it. You just say BCI or neurotech and everyone gets it in Silicon Valley*”. Six technologists, from each of the three countries, had been previous recipients of direct or indirect DARPA funding, including the two technologists who were not aware of dual-use, with each citing that military funding had been beneficial, easier to attain than state government grants, and that their specifically funded projects were unlikely to be used directly for military purposes.

The notion of advancing science or technology was raised throughout the interviews, with three technologists referencing the idea of a capabilities race being felt both within nations and internationally, citing the term “*technological supremacy*” as being at the forefront of many researchers’ minds. They explained concerns about “*unregulated nations*” were emerging, creating a global landscape for neuroscience.

(3) A sense of responsibility?

All the interviewed technologists viewed the notion of responsibility as shared by the relevant stakeholders. They felt responsibility at an individual researcher level should encompass monitoring the technology’s efficiency, efficacy, and encouraging further consideration of potential alternate applications of a technologist’s work. Five of the technologists stated there it was an individual researcher’s responsibility to consider DU application of their technology, each attributing importance on how possible DU is revealed, open or closed publication access, and consideration of low probability but high impact scenarios. At an institutional level, they highlighted the responsibilities of universities and institutions to ensure adequate training and monitoring of institutional oversight. Multiple participants had been involved in ethics committees, writing chapters and articles, and presenting lectures on researcher responsibility. One participant stated: "*working with the European Commission always has a two edge feel to it. They fund open research and demand you publish it openly and then expect you to support commercial innovation because commercial innovation depends on having some kind of proprietary control of intellectual property*" *(Interviewee 1).* Another participant expressed: "*The expectation of openness changes from different funding bodies. I'm a strong believer in open science, and open data is part of that" (Interviewee 2).*

Societal involvement was also highlighted as a responsibility to increase awareness of technological advances and to allow for broader perspectives as to whether the technologists continue their scientific work. One participant stated "*I almost wonder if it's like a Pandora's box – once this technology is out there you can't put it back in" (Interviewee 7)*. Several technologists raised the possibility of neurotechnology being used for subliminal or direct marketing campaigns, with accessibility to brain data becoming easier with platforms like *Facebook*, *Google*, and Elon Musk's emerging BCI company *Neuralink*, and they said people ought to be warned about this. A need for a global perspective with regard to responsibility and access, due to increased research tourism to, and collaborations with, less regulated countries was also frequently stated.

(4) Possible unintended consequences

Enhancement featured heavily in discussions of unintended consequences. Most participants did not have an issue with enhancement, citing that it was an inevitable progression of the human species, and emphasising the importance of taking a long view on the matter. Enhanced soldiers were considered an ethical grey area because it would be creating a *"superhuman with abilities beyond what nature has provided"(Interviewee 8),* whom were not being enhanced for clinical or restorative purposes but for warfare. Enhancement for weaponization purposes increases the potential of harmful applications and prompts an avenue of further ethical investigation. Two technologists mentioned they had been involved in trials focusing on improving performance of pilots using BCI technologies. Impressions gathered about enhancement of the general population tended to perceive restoration positively, with cochlear implants being cited as an example of a positive neurotechnology application, whilst augmentation was seen as making society more uncomfortable. Several participants suggested that to define enhancement, a universal baseline is necessary. In contrast, other participants perceived enhancement neurotechnology as an application to be understood as an improvement tool.

When asked about access to such neurotechnology applications, issues of maldistribution both within and between countries, distributive justice and expanding irregularities in intelligence and class were raised. In regard to possible consequences of using their technology as a form of enhancement, a number of participants described it as still *"science fiction"*, that their technology was *"not there yet"*, with concerns of long term effects and risks being unknown, and that ultimately it was impossible to be technological and economical *"fortune tellers*".

Discussion

Dual use as multifaceted

One of the central findings of the study was that the term 'dual-use' is multifaceted. The concept of dual–use was known to the majority of participants, even though they did not consider it to directly apply to their own work. The notion of being "away from the front line" may work as a researcher shield or deflection from having to consider possible dual–use implications too deeply. Indeed, other studies suggest neuroscientists are more likely to consider their colleagues' work as having more potential dual–use risk than their own work. [11] Our study also demonstrated that whilst DARPA indirectly funded more than half of the participants, the participants did not believe their scientific work was being applied for military application. However, it was recognised that there is still the possibility that their research could be later applied for military purposes. There is minimal practical guidance available to assess the risks of neurotechnology applications being used for harm, or to determine the potential contribution of these applications to military programs.

Of additional significance was that the two technologists producing DTC neurotechnology had not encountered the concept of dual–use, which may be reflective of a broader lack of awareness amongst technologists producing DTC neurotechnologies. Whilst opinions from two participants is not generalizable, it may be indicative of the degree of socio-ethical understanding and consideration of those involved in the commercial enterprise of neuroscience.

Frequent requests for clarification of the definition of dual–use throughout the interviews suggest the term is not clear to researchers. Mahfoud et al. argue the term dual–use should be reconsidered and that failure to move away from this dualistic framework could result in an inability to govern its circulation, particularly with regard to those who fund, develop and regulate research in neurotechnology and neurorobotics. [7] This study's findings complement this recommendation, with the binary aspects of dual–use not being perceived by our participants as cohesive to their neurotechnological research.

The commercialization of neurotechnology

In 2019, the neurotechnology market was estimated to generate over USD $12 billion in annual sales by 2021. [12] To achieve commercial gains, companies specifically target technological products that are attractive for military, security and defence contacts with many of the products being centred on communication technologies, robotics and artificial intelligence. [5] Venture capitalists have increasingly been investing in brain science, with angel investors in Silicon Valley contributing vast amounts of funding to biotechnology start-ups. Prominent technology investors such as Elon Musk and his *Neuralink* project, or technology companies crossing over academic research and commercial innovation such as DeepMind (https://deepmind.com/) or Bitbrain (https://www.bitbrain.com/) indicate a change in the future of neuroscience funding, which may promote benefits like wider access to neurotechnology, but also, as the study participants noted, increase harms through the marketization of personal brain data and private companies becoming privileged beneficiaries and gatekeepers of vast amounts of brain data. This creates potential for malevolent application of neuroscience and neurotechnology in civilian, political, security and commercial applications. Certain neurotechnology such as DTC BCI wearables, which are not being sold for clinical benefit, have the capacity to be made readily available on the market, without rigid ethical approval requirements. Whilst dual–use has traditionally been defined as scientific findings that can be used for military and civilian applications [13, 14], the commercialisation of neurotechnology opens up a less distinct, more hybrid form of use.

Study participants noted that the DTC neurotechnology wearable marketplace is growing, with cheap and operational tools being used to enhance cognitive performance. They also noted increasing do-it-yourself ‘neurohackers’ who attempt to optimise their cognitive capacities with the consumer kits being developed.[15 -17] As the applications for neurotechnology broaden, the potential for dual–use increases with malicious biohacking, dangerous uses of medical neuromodulation, and neuroimaging-based intelligence interrogations all becoming possible. [18] Whilst a confirmed case of a malicious attack is yet to be reported, the feasibility of obtaining private information without authorisation from users of EEG-based BCIs has been demonstrated. [19] While the FDA has declared DTCs “low-risk”, concerns about possible harms have been raised [1, 20] and calls are emerging for responsible innovation and better engagement for DTC BCI technologies. [21, 22] A starting point to address these concerns may include opening up dialogue with the technologists, investors and ethicists.

A globalised neuroscience research landscape

The acceleration of global advances in neuroscience were interpreted differently between the technologists and the neuroethicists. The former described it as “*competitive*” and a “*capabilities race*”, and the latter as a “*collaborative*” form of research tourism. This discrepancy is significant as it provides an insight into the participants’ distinct views. If neurotechnologists perceive their field as competitive and as a race to achieve further understanding of the brain, it may leave little room for socioethical consideration of future implications. The variance of socioethical regulations poses a risk of, what one neuroethicist described as, *“ethical dumping”*, where it is assumed all nations will adhere to western values and moral standards. Without an overarching international set of responsible researcher guidelines for neuroscience and neurotechnology, a space for (unregulated) research tourism remains. This was illustrated by two participants who had moved from Australia to the US specifically to accelerate their research. The InterAcademy Panel views researchers as a global community and recommends they participate in discussions about possible consequences generated from their work, recognising the intricacies open access research and stricter government oversight as on going challenges. [23]

Key potential harms raised by participants that they saw stemming from an increasingly globalised neuroscience landscape were the inequality and maldistribution of neuroresearch and neurotechnologies between and within countries. As state and non-state actors form neuroscience research teams, without having an overarching international set of responsible researcher guidelines for neuroscience, a lucrative research tourism market will be created.. Some saw this as inevitable: "*Disparity in health delivery across the world is already a major problem. The wealthy versus the poor countries. I don't have a solution to that, but I would say you can't halt the development of technology because it's not going to be equally distributed just because people won't be able to afford it"(Interviewee 7).* In other words, wealthy countries are able to remain rich by using biotechnology and government procurement of defence technologies, which contribute to competition between wealthy countries by securing a dominant share of new markets. [24] Other participants felt active efforts should be made to redress the situation. One of the neuroethicists voiced concern about intellectual property laws, whereby the powers of ownership and control depend on the country and the researcher within it. Variations of intellectual property laws between regions can mean that a therapeutic device might be patented but novel treatment methods cannot be patented. If a state owns everything generated within its boundaries, this may be contrary to the perceived competition between states that the participants felt and might behold a conflict of interest for technologists who seek funding from countries outside of their own. Development of a 'neuroeconomy' may embolden inflated claims of successful neuroscience research and rush products to market. [25] A neuroeconomy encourages commercial companies who significantly fund universities, departments, or research centres to gain priority patent rights, an increased tendency to inflate research and capitalise on scientific knowledge. [25]

Conclusion

With a growing number of experts now being able to use technologies of anticipation to envision the possibilities and potential problems emerging from neuroscience, Rose and Abi-Rached argue that authorities have an obligation to govern both the present and the future of brain research. [25] Fears of creating a technocentric Pandora's Box were voiced by participants, but whether a technocentric Pandora's Box has already been opened is subjective, and dependant on the perceived impacts neurotechnology has already had on society. An example is Musk's previously mentioned *Neuralin*k, a start-up company which aims to form "*a symbiosis between AI and the human brain*". [26] *Neuralink* aims to allow humans with spinal cord paralysis to control phones or computers. This neurotechnology (provided Musk's promissory claims translate into actual capacity to deliver) may be perceived as a friendly application, if not therapeutic, and has generated much public interest. However, it also holds great dual–use potential, including possibilities for neurohacking or thought-hijacking at a user level, as well as privacy intrusions from state and non-state actors via smartphone, computer or cloud access or vice versa, and even possible manipulation from the AI systems operating the brain chip.

Whilst transparency and openness in scientific research have been promoted for a long time (e.g. British Royal Society for Social Responsibility 1969-1991, and more recently the RRI framework in the EU [27]), the ability to control emerging technology and its possible unintended effects remains challenging. Moreover, open science should not be taken as a potential silver bullet and can also lead to potential unforeseen dual-use applications. This was recently demonstrated by the use of Reinforcement Learning, pioneered by DeepMind and the object of ongoing developments for the promises it holds for neuroscience research [28], in the DARPA's AlphaDogfight trials (https://www.darpa.mil/news-events/2020-08-07), where a US company used it to create an algorithm that defeated a human F-16 pilot in a simulation. [29]

The perceptions gathered in the pilot study indicate that most, though not all, technologists were aware of dual–use, but that they viewed it as: multifaceted and fluid, with the commercialisation and globalisation of the emerging science shifting understandings of 'beneficial' and 'harmful' neurotechnologies and rendering future uses unknowable.

Study participants were acutely aware that what they intend for an application and how that technology is eventually applied can be two very different things. They did not perceive dual–use as binary, as black and white. Instead of a one-off event, consideration of potential future harms and benefits should therefore be thought of as a continuous process, and one that encompasses informed involvement and distributed responsibility across multiple stakeholders at a globalised level. It is not just the responsibility of the individual researcher but other stakeholders involved in scientific research should also be accountable and actively promote inclusive deliberation and reflexivity. Scientific institutions, funders and publishers all have roles to play in managing the uncertainties and risks of harm and from emerging technologies.

The study also highlights that stakeholders need better tools to assess the practical and socioethical implications of neurotechnological innovations and their possible future applications. Agreement on what is perceived as beneficial or as harmful will need to be actively reached on a case-by-case basis – and the consequences of mis-estimating outcomes and impacts ought to be considered part of the equation too.

Given the small sample size of this study, further investigation into technologist's perceptions is needed to formulate an explanatory theory. A future study would include a cross comparison study of technologist's perceptions on DU and ethical responsibility from the UK and the USA, particularly in regard to the different funding bodies available and the differing ethical guidelines between the BRAIN Initiative and the Human Brain Project.

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