

Perspective of Ethical Issues Associated with Cognitive BMI

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Abstract. With their rapid development and huge potential, brain-machine interfaces (BMIs) will become one of the most important technologies in human society within decades. However, the ethical framework around this technology is far from mature. This paper seeks to summarize, analyze, and provide solutions to ethical issues associated with a particularly transformative family of BMIs - cognitive BMIs. 18 articles were included in this review through a structured article selection process. The discussion of the ethics of cognitive BMIs is divided into six topics: (i) individual cost-benefit balance; (ii) privacy and cybersecurity; (iii) autonomy, authenticity, and responsibility; (iv) equality; (v) cultural issues; (vi) military dual use. Within each topic, ethical issues that appeared in the reviewed articles are discussed, and solutions or directions for approaching them are given.

Keywords: Brain-machine Interfaces, Cognitive Neurotechnology, Ethics, Neuroethics

1. Introduction

Brain-machine interfaces (BMIs) are a technology that bridges the brain and machines like prostheses, stimulators, and computers. For example, a BMI device can decode the electric activity of motor neurons in the frontal lobe and use the decoded signals to control a robotic arm. Both in a technological and industrial sense, BMIs are blooming. It is reasonable to predict that in the close future, BMIs will appear in various scenarios in our lives.

However, before a technology - especially one that is as powerful as BMIs - is applied, ethical considerations are necessary. After countless debates among geneticists, philosophers, lawmakers, and the public, an ethical scaffold has been established for genetic technologies. The scaffold draws clear boundaries among technologies that can be utilized without ethical concerns, technologies that can now be used since surrounding ethical issues can be resolved, and technologies that should be prohibited because of unresolved or irresolvable ethical issues, such as gene-edited human babies. Yet, in the family of bioethics, neuroethics is still an immature branch [1]. As a result, BMIs lack an ethical scaffold. This paper's large goal is to contribute to such a scaffold.

This paper places its focus on cognitive BMIs - BMIs that decode and/or influence cognitive functions, such as memory, language, and decision-making. So, BMIs that purely interact with motor-sensory or emotional modalities are not the focus of the paper. (Nonetheless, emotions have profound interactions with cognitive functions, so several articles on affective BMIs were included in this review.) Functions cognitive BMIs can accomplish include: (1) Monitoring cognitive processes. (2) Restoring impaired cognitive functions. (3) Enhancing a healthy mind. The paper's interest in cognitive BMIs stems from their profound implication. What differentiates humans from animals? Upon this "Big Question", many positions are taken, but most of them agree that the difference lies in cognition. So, unlike motor-sensory and affective BMIs, cognitive BMIs directly interact with what makes us humans; they even have the potential to transform humans into more different beings. Therefore, cognitive BMIs must be carefully applied, to which end meticulous ethical considerations are needed.

The reason that BMIs lack an ethical scaffold is not that researchers are indifferent. In papers that describe new BMI advancements, authors often raise and discuss the ethical issues implicated by the advancements. Papers that focus on specific categories of ethical issues (e.g., safety) or ethical issues of a specific BMI application (e.g., memory enhancement) are also common. However, efforts to integrate the scattered ethical considerations into a single body of knowledge are dearth. The purpose

of this paper is to overview the ethical issues associated with cognitive BMIs and possible measures to address the issues.

2. Methods

There are three types of review that can fulfill the purpose of this paper - a narrative review, a scoping review, or a systematic review [2]. The paper chose to conduct a narrative review for the following reasons. First, the paper only aims to synthesize the ethical issues surrounding cognitive BMIs and give a qualitative analysis, so a narrative review is sufficient. Second, a systematic or scoping review requires two reviewers, but the paper only has one author.

Traditionally, a narrative review does not need a "methods" section. However, because of criticisms about the unstructured nature of this type of review, it is recommended for authors to construct narrative reviews with a pre-defined, explicitly presented protocol [2]. Adapting the guideline for narrative reviews provided by [3] and borrowing the guidance for scoping reviews given by Joanna Briggs Institute [4], this paper conducted the review in four steps:

- (1) identifying the research questions
- (2) setting the search strategy
- (3) screening and eligibility check
- (4) charting the results

2.1. Research questions

This paper has two research questions.

- (1) What ethical issues are associated with cognitive BMIs?
- (2) How can these issues be addressed?

2.2. Search strategy

Since this is a narrative review, there was little concern about the possible bias caused by the selection of databases or the use of search terms. The databases used were PubMed and Web of Science.

On the databases, the following search terms were used: ("cognitive" OR "cognition") AND ("Brain-computer interface" OR "Brain-computer interfaces" OR "BCI" OR "Brain-machine interface" OR "Brain-machine interfaces" OR "BMI") AND ("ethics" OR "ethical"). No limits were placed on the year of publication or the article type. Since ethical issues did not need to be the major topics of valuable articles, secondary searches were conducted.

After the search was completed, duplicate articles were removed.

2.3. Screening and eligibility check

The inclusion criteria were:

- (1) In the title, the abstract, or the keywords, BMIs and ethics are mentioned
- (2) Specific ethical issues are discussed.
- (3) The ethical issues discussed are directly (not necessarily exclusively) related to cognitive BMIs.
- (4) The article is written in English.
- (5) The article can be accessed with full text.

The exclusion criteria were:

- (1) Ethical issues are only listed as words, phrases, or single sentences without any discussion.
- (2) Only the ethics of BMI research, but not that of BMIs themselves, are discussed.
- (3) The article is a paper on the width or depth of the ethical discussion among a certain group, e.g., nurses, through a certain medium, e.g., newspaper, or in a certain region, e.g., China.

Following these criteria, the author screened the articles by scanning. Then, the author read the articles that passed the screening phase in full text to check if they were eligible for this review.

2.4. Charting

The following data were manually extracted and charted:

- (1) Authors
- (2) Title
- (3) The context for ethical issues, i.e., the related cognitive BMI technique(s) and/or application(s)
- (4) General ethical topic(s)

The charting was performed with Microsoft Excel for Mac version 16.56.

3. Results

The search on WOS and PubMed yielded 84 and 99 articles, respectively. 29 duplicates were detected and removed. Then, 136 articles were excluded through the screening criteria. All 18 articles that passed the screening were deemed eligible for this review.

The data extracted from the 18 included articles were presented in Table 1.

Table 1. Results of the article selection process

Authors (year)	Title	Related BMI technique(s) and/or application(s)	Ethical Topics
Abbott and Peck, (2016)	Emerging Ethical Issues Related to the Use of Brain-Computer Interfaces for Patients with Total Locked-in Syndrome	communication with total LIS patients	1. surrogate decision 2. autonomy 3. end-of-life care 4. pediatric care
Cinel et al., (2019)	Neurotechnologies for Human Cognitive Augmentation: Current State of the Art and Future Prospects	cognitive enhancement	1. privacy 2. responsibility 3. safety and harms 4. reliance
Dobkin, (2007)	Brain-computer interface technology as a tool to augment plasticity and outcomes for neurological rehabilitation	cognitive rehabilitation	1. informed consent from locked-in patients 2. reliance 3. safety and harms
Bonaci et al., (2014)	Securing the Exocortex: A Twenty-first Century Cybernetics Challenge	non-invasive BMIs	privacy
Klein et al., (2016)	Brain-computer interface-based control of closed-loop brain stimulation: attitudes and ethical considerations	closed-loop DBS	1. authenticity 2. effects on relationship 3. consent
Ali et al., (2020)	Efficacy of Neurofeedback Interventions for Cognitive Rehabilitation Following Brain Injury: Systematic Review and Recommendations for Future Research	NFT for cognitive rehabilitation	1. unproven effectiveness and limited benefits 2. safety and harms
Schmitz, (2011)	The Neurotechnological Cerebral Subject: Persistence of Implicit and Explicit Gender Norms in a Network of Change	military prosthetics and TMS for cognitive enhancement	gender norms

Krol et al., (2020).	Cognitive and affective probing: a tutorial and review of active learning for neuroadaptive technology	cognitive probing	1. responsibility 2. privacy and consent
Cannard et al., (2020).	Self-health monitoring and wearable neurotechnologies	self-monitoring	1. reliance 2. safety and harms
Coin and Dubljević, (2020).	The Authenticity of Machine-Augmented Human Intelligence: Therapy, Enhancement, and the Extended Mind	intelligence augmentation	authenticity
Pugh et al., (2018)	Brainjacking in deep brain stimulation and autonomy	DBS	1. autonomy 2. consent
Micoulaud-Franchi et al., (2013)	Cyborg psychiatry to ensure agency and autonomy in mental disorders. A proposal for neuromodulation therapeutics	non-invasive electrical brain stimulation and NFT for treatment of psychiatric disorders	autonomy
Ienca, (2018).	Democratizing cognitive technology: a proactive approach	military applications, cybercrime, and mass surveillance	1. military dual use 2. cybersecurity
Val-Laillet et al., (2015)	Neuroimaging and neuromodulation approaches to study eating behavior and prevent and treat eating disorders and obesity	neuromodulation for studying eating behavior and treating eating disorders	1. cost-benefit balance 2. stigma 3. free-will
Moxon et al., (2019)	Mind Over Matter: Cognitive Neuroengineering	cognitive enhancement	1. wealth equality 2. privacy and cybersecurity 3. responsibility
Khan and Aziz, (2019)	Transcending the brain: is there a cost to hacking the nervous system?	commercial actions of large companies, private cognitive enhancement, and military applications	1. privacy 2. autonomy 3. equality 4. military dual use
Synofzik and Schlaepfer, (2008)	Stimulating personality: ethical criteria for deep brain stimulation in psychiatric patients and for enhancement purposes	DBS for treatment of psychiatric disorders and cognitive enhancement	1. change of personality 2. autonomy 3. justifiability of enhancement 4. cost-benefit balance
Ienca et al., (2018),	Brain leaks and consumer neurotechnology	self-monitoring and private non-invasive brain stimulation	privacy

Several BMIs developed for neurological rehabilitation or as treatment of psychiatric disorders were counted as cognitive BMIs because the disabilities or diseases, they cope with impair patients' cognitive functions.

Since this review, despite being narrative, followed a pre-defined structure commonly used by systematic reviews, a PRISMA flow diagram [4] was used to illustrate the article selection process (Figure 1).

4. Discussion

This section is divided into six subsections, each covering a major ethical topic. In each subsection, ethical issues belonging to the subsection's topic and solutions to these issues, or directions for approaching them if the issues are not immediately solvable, are discussed. The discussion will not get into the technical details of various cognitive BMI devices but will focus on the underlying ethics.

4.1. Individual cost-benefit balance

For every technology, a major ethical consideration is whether it brings larger benefits than costs to its users. The first category of cost to consider is physical and mental harm. Cognitive BMIs, especially invasive ones, are risky. For example, the implantation of rehabilitating neuroprosthesis can cause obsessive and delusional thoughts as well as perceptual distortion [5]. Deep brain stimulation (DBS) may lead to adverse effects such as hemorrhages, depression, and cognitive impairments [6]. To lower these risks, researchers need to carry out more studies and trials to advance the technologies and ensure that they are safe in practical use. Besides, neuroimaging could help adjust the parameters of BMIs according to the traits of individual brains [7].

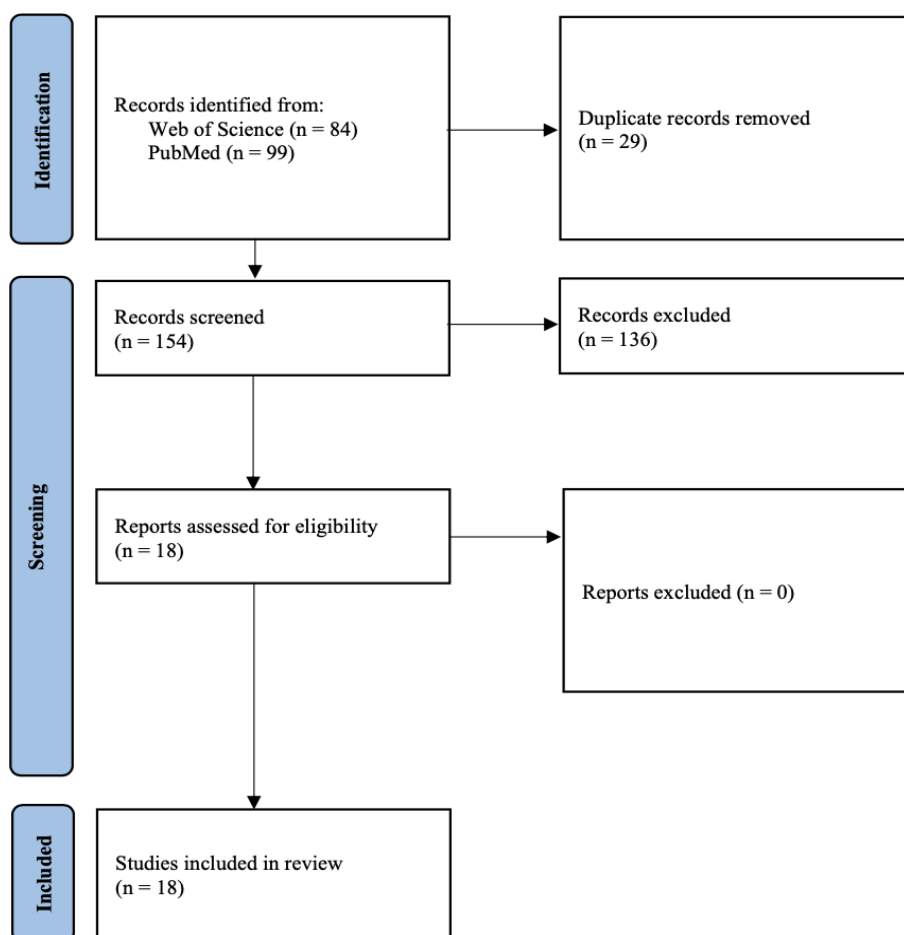


Figure 1. The PRISMA flow diagram

Another potential harm of cognitive BMIs is reliance. If patients cognitively rehabilitated by BMIs lose the ability to use BMIs for reasons like the progression of neurodegenerative diseases, the re-deprivation of cognitive functions can lead to even more suffering than if BMIs are never used. Patients with psychiatric diseases treated by BMIs can face a similar situation. Technological advancements that make BMIs more stable can reduce the possibility of such suffering. Furthermore, every patient should be informed of the risk of BMI deprivation, so he/she can take this risk into consideration while making decisions and be prepared for a life without the functions enabled by his/her BMI device(s).

Besides medical BMIs, cognitively enhancing BMIs can also create reliance, possibly leading to the deterioration of cognitive functions they enhance [8]. None of the reviewed articles, however, propose any solution to this issue. Animal models can help determine the long-term effects of BMI-based cognitive enhancement. If the proposed deterioration is observed, over-reliance on BMIs must be prevented through a synergic effort made by researchers, policymakers, and the public.

Theoretically, cognitive BMIs promise huge benefits to their users. They can be used to treat psychiatric disorders [6, 9, 10], rehabilitate the cognitively disabled [5, 11], and augment human cognition [12]. Nonetheless, to what extent these benefits can be realized is questionable. Two of the reviewed articles offer valuable perspectives on this question.

[11] points out that the effectiveness of neurofeedback therapies (NFTs) is dubious because of the insufficiency of empirical support. Furthermore, a large portion of the limited evidence likely comes from dishonest researchers and biased publishers. It is predictable that every new cognitive BMI technique, no matter therapeutic or enhancing, will face these problems. Solving them requires not only more research but also more rigorous research and publication ethics in the field of BMIs.

Focusing on DBS, [6] argues that although the technique has a verified and outstanding effectiveness in treating psychiatric disorders such as obsessive-compulsive disorder (OCD), this cannot be directly equated with an improvement in patients' quality of life. This concern can be extended to all types of cognitive BMIs since there is always a discrepancy between scores in cognitive tasks and happiness. To address this issue, as [6] suggests, researchers should include quality-of-life parameters in their criteria when evaluating cognitive BMIs.

4.2. Privacy and cybersecurity

Cognitive BMIs can decode users' mental activities. This feature raises severe ethical issues about privacy and cybersecurity. Currently, most "mind-reading" techniques, such as decoders based on simple neuroimaging techniques, can only read neural activities that users voluntarily choose to expose [13]. Nonetheless, techniques like cognitive probing, which can read implicit mental activities and use them to perform active machine learning, have already been developed [14]. Access to thoughts that are not meant to be known is a dreadful intrusion into privacy. Such access can even give rise to the threats of cyberterrorism and cyberwarfare [15]. A solution to this issue is to use a BMI anonymizer to conceal all unintended information [16]. Yet, one can never be certain that a cybersecurity tool is free of loopholes. A better solution, thereby, is the enforcement of transparency - users should be informed of the nature of the data that can be extracted from their minds [14].

However, whether the extraction of a piece of mental information is intended or not, third-party access to the piece can menace the privacy of its owner. This third party can be a "brain hacker" who puts the data for criminal use [17], a large company that wants users' attitudes, preferences, and medical conditions for neuromarketing [18], or a national intelligence agent that monitors users' thoughts for surveillance [15]. This issue is not limited to BMIs that are specifically designed for "mind-reading," since the decoding of cognitive activities is a key feature of any cognitive BMI. To prevent the unauthorized use of neural data, the transparency mentioned above should be extended to letting users know how and by whom their data will be used [14]. Additionally, laws and regulations on the utilization of neural data should be established before cognitive BMIs that may infringe users' privacy are widely applied [19].

4.3. Autonomy, authenticity, and responsibility

Among the reviewed articles, autonomy is the most frequently mentioned as well as the most complex ethical topic. A simple definition of autonomy is the ability to govern oneself, i.e., the ability to perform informed, uninfluenced decision-making. In this sense, for a person using cognitive BMIs to be autonomous, he/she must be able to give informed consent to the use. However, this is difficult for users receiving cognitive BMIs for neurological rehabilitation or the treatment of psychiatric diseases. It is impossible to obtain consent from patients with total locked-in syndrome (tLIS), who retain consciousness yet cannot communicate with their external environment by any means [7]. On

the other hand, patients with mental illnesses like OCD can often have their decisions influenced by their conditions or the desperation of being ill [5, 9]. These issues are characterized by complicated ethical dilemmas. Cognitive BMIs can restore the autonomy of tLIS and OCD patients, enabling the former to communicate their decisions and the latter to be uninfluenced by compulsions; yet, in certain circumstances, applying cognitive BMIs can violate the principle of informed consent. Further complications can arise in various scenarios, e.g., when patients decide to impair or abandon their autonomy by stopping the use of cognitive BMIs.

Due to the intricacy of the above dilemmas, issues related to informed consent should be solved in a case-by-case manner, following consistent ethical guidelines. Synthesizing the analyses by the reviewed articles [5, 9, 20, 21], the guideline should at least include: (i) if the user is able to make decisions but has impaired cognitive or affective abilities, a psychological assessment needs to be performed to ensure that the user is not influenced by any mental disorder; (ii) the user's decision must not be a result of coercion. (iii) the user must fully understand the nature, methodology, and purpose of the technique that will be applied to him/her. (iv) if the user satisfies the three conditions above, respect his/her decision. (v) if the user is unable to give informed consent but has a surrogate, respect the surrogate decision. (vi) if for restoring the user's autonomy, third-party application and/or control of cognitive BMIs should be considered. (vi) in any case that the autonomous decision conflicts with the user's autonomy, further evaluation is needed, and an eclectic decision, e.g., removing the communicative BMI from a tLIS patient but restoring the communication once a month, should be considered.

Even if applications of cognitive BMIs are results of informed consent, users' autonomy could still be harmed. Techniques like neuromodulation - the modulation of neural networks for improving affective states and/or cognitive abilities through repetitive transcranial magnetic stimulation (rTMS), DBS, etc., no matter for medical [7, 10] or enhancing [18] purposes, undoubtedly cast influences on users' decision-making. While approaching this issue, it is useful to use authenticity as a proxy for autonomy. Authenticity refers to the state where one can attribute his/her actions and results to his/her true self. One argument against cognitive BMIs such as neuromodulation is that they harm users' authenticity by altering their personalities. However, according to [6], this argument is invalid because personality does not only include one's psychological traits. Instead, it is composed of processes ranging from low-level sensorimotor functions to high-level cognitive functions. Therefore, a change of personality is not an adverse effect, but the very purpose of any intervening cognitive BMIs. Another compelling argument for cognitive BMIs is that they are nothing different from other tools humans develop [12]. As long as the use of Braille by blind people to learn languages and the enhancement of one's computational ability with a calculator do not harm authenticity, so do cognitive BMIs. Therefore, cognitive BMIs that are used under informed consent should not be questioned for a threat to authenticity or autonomy.

Another issue related to autonomy is the responsible party. Cognitive BMIs, especially newly developed ones, can be inaccurate both in the encoding and decoding phases [13]. If the inaccuracy causes untoward behaviors, it needs to be determined if the user or the provider of the technique is responsible. A straightforward solution is integrating the possibility of inaccuracy into informed consent through a liability waiver [14]. Nonetheless, this is only a practical solution but does not address the underlying ethical conflict. Therefore, an autonomy approach should be taken. By the standards discussed before, if a user can be considered autonomous in an action, then he/she is liable for it; otherwise, the BMI company is liable. This approach simultaneously addresses the problem when morally unacceptable or criminal actions are performed under the third-party control of users' cognitive BMIs [21]: since users are not autonomous, the third party is to be condemned.

4.4. Equality

Cognitive BMIs present an unignorable challenge to equality. Since there are already many expensive medical interventions and none of them are abandoned for the inequality they bring, it is particularly valuable to discuss the equality issue in the context of cognitively enhancing BMIs. As

[19] points out, the high prices of new techniques tend to create a situation where only wealthy people can afford augmentations such as heightening general intelligence. This potentially leads to severe inequality of life opportunities and social immobility. [18] warns that the growing privatization of the health sector can compound this issue, making the future world a dystopia.

But it is also wrong to be overly conservative. Humans are constantly seeking improvements in cognitive abilities through coffee, real-time translators, computers, etc., but these are not regulated or banned because some people cannot afford them. The concept of positional good can be introduced to solve the equality issue. The positionality of a good depends on how much of its value comes from its distribution in society. A positional good provides not a genuine benefit but an advantage over others. Athletic stimulants, which are prohibited, are mostly positional, for their value stems from a better performance over other athletes; Computers, the usage of which is promoted, are mostly non-positional, for their value comes from higher productivity and better entertainment. Just like these two examples of enhancing technology, cognitively enhancing BMIs should be evaluated based on their degrees of positionality; the more positional a technique is, the more it should be taxed, regulated, or prohibited.

4.5. Cultural issues

Cognitive BMIs that are designed for disabled or psychiatrically disordered people can be viewed as stigmatizing by their potential users. Many patients, such as those with eating disorders [7], recognize their disability or mental illness as part of their identity. From their perspective, efforts to improve conditions can deny their identity, implying that they are not normal. Using a utilitarian approach, it is easy to conclude that a world where people are free of the pain and the inconvenience brought by disability and illness is a better world. Nonetheless, patients' autonomy must be respected. Therefore, as [7] suggests, careful and extensive scientific communication is needed to let patients know that cognitive BMIs are designed to improve their lives but not to stigmatize them.

Another cultural issue is that gender norms may be strengthened by cognitively enhancing BMIs. The reason is that the enhancements they provide are often associated with masculinity. An example given by [22] is the "Cognitive Threat Warning System," a military BMI technique that enables soldiers to react faster to dangerous stimuli. This technique signifies the valuing of alertness, an exemplary male quality. The stereotyping effect is similar to that of a trend of muscle training: although women can be muscular as well, the fact that muscles are strongly associated with masculinity makes the trend a reinforcement of the norms of males and females. Historically, gender research has had a huge contribution to the separation of certain qualities from specific genders. Therefore, solving the gender issue requires extensive gender research, especially in conjunction with neuroscience and BMIs.

4.6. Military dual use

As mentioned in the last subsection, cognitive BMIs can have military applications. These applications include the restoration of cognitive functions of injured soldiers, the cognitive enhancement of healthy soldiers, and interrogation [15]. As [18] argues, the development of these applications is fostered by the recent global tension. These applications make cognitive BMIs a dual-used technology - a technology that has civil and uncivil uses at the same time. The purpose of BMI technology is to give unhealthy and healthy people better lives. Military uses, with the purpose to strengthen life-harming forces, contradict this purpose. Luckily, a solution to this issue can be borrowed from the numerous precedents where technology is used for military purposes: an international agreement to not use cognitive BMIs in the military, or at least not for enhancement or interrogation purposes, should be formed.

5. Conclusion

This paper conducted a narrative review with reviewed articles selected via a presented, structured process. The main findings of the paper are the numerous ethical issues associated with cognitive BMIs. The issues cover six main topics: (i) individual cost-benefit balance; (ii) privacy and cybersecurity; (iii) autonomy, authenticity, and responsibility; (iv) equality; (v) cultural issues; (vi) military dual use. Among these issues, some, e.g., the threat posed by cognitive BMIs to authenticity given informed consent, are proved to be unproblematic, but most, e.g., the privacy intrusion by mind-reading techniques and the military dual use of BMIs, demand solutions before related technologies become popularized.

This paper is a useful source for bioethics scholars who want to perform an in-depth analysis of a particular issue or cognitive BMI researchers who want to discuss the ethical implications of their technique. Also, policymakers can refer to this paper when they are considering subsidies, regulations, international agreements, etc. on cognitive BMIs.

It is to be noted, however, that some issues discussed are so complex that this paper only gives guidelines for solving them instead of detailed solutions. So, research on the theoretical specifics and the implementation of the solutions is a recommended future direction. In addition, because of the narrative nature of this review, it bears the problem of incomprehensiveness both on the ethical issues and their solutions. Hence, a scoping or a systematic review may be done in the future to provide a more comprehensive view.

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