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NEUROTECNOLOGIA E FILOSOFIA DA NEUROCIÊNCIA: DESAFIOS ÉTICOS E ONTOLÓGICOS NA ERA DAS INTERFACES CÉREBRO-COMPUTADOR

NEUROTECHNOLOGY AND PHILOSOPHY OF NEUROSCIENCE: ETHICAL AND ONTOLOGICAL CHALLENGES IN THE ERA OF BRAIN-COMPUTER INTERFACES

NEUROTECNOLOGÍA Y FILOSOFÍA DE LA NEUROCIENCIA: DESAFÍOS ÉTICOS Y ONTOLÓGICOS EN LA ERA DE LAS INTERFACES CEREBRO-COMPUTADORA

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RESUMO: Esse artigo buscou como objetivo analisar os avanços recentes na neurotecnologia e discutir seu impacto na filosofia da neurociência, com especial atenção aos desafios éticos e ontológicos que eles representam. O estudo adota uma abordagem qualitativa, teórico-analítica, baseada em uma revisão narrativa da literatura científica internacional publicada entre 2020 e 2025, incluindo fontes indexadas como a *Stanford Encyclopedia of Philosophy*, *Nature*, *Neuroethics* e *Oxford Handbooks*, bem como obras clássicas da filosofia. A análise mapeia neurotecnologias atuais e emergentes, como interfaces cérebro-computador, neuropróteses e técnicas de modulação da memória, e examina suas implicações éticas, incluindo questões de privacidade mental, identidade e aprimoramento humano. Os resultados destacam que as neurotecnologias não apenas expandem a compreensão científica do cérebro, mas também desafiam as concepções filosóficas tradicionais de personalidade, liberdade e responsabilidade moral. O estudo conclui enfatizando a necessidade urgente de estruturas regulatórias robustas e diretrizes éticas para garantir que o desenvolvimento tecnológico promova a dignidade humana, a liberdade cognitiva e a justiça social, em vez de reforçar as desigualdades ou comprometer a autonomia.

Palavras-chave: Neurotecnologias. Neuroética. Filosofia da neurociência. Natureza humana. Interface cérebro-computador.

ABSTRACT: This article aims to analyze recent advances in neurotechnology and discuss their impact on the philosophy of neuroscience, with special attention to the ethical and ontological challenges they pose. The study adopts a qualitative, theoretical-analytical approach, based on a narrative review of international scientific literature published between 2020 and 2025, including indexed sources such as the *Stanford Encyclopedia of Philosophy*, *Nature*, *Neuroethics*, and Oxford Handbooks, as well as classic works in philosophy. The analysis maps current and emerging neurotechnologies such as brain-computer interfaces, neuroprostheses, and memory modulation techniques and examines their ethical implications, including issues of mental privacy, identity, and human enhancement. The results highlight that neurotechnologies not only expand scientific understanding of the brain but also challenge traditional philosophical conceptions of personhood, freedom, and moral responsibility. The study concludes by emphasizing the urgent need for robust regulatory frameworks and ethical guidelines to ensure that technological development promotes human dignity, cognitive liberty, and social justice, rather than reinforcing inequalities or compromising autonomy.

Keywords: Neurotechnologies. Neuroethics. Philosophy of neuroscience. Human nature. Brain-computer interface.

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RESUMEN: El objetivo de este artículo es analizar los avances recientes en neurotecnología y debatir su impacto en la filosofía de la neurociencia, prestando especial atención a los retos éticos y ontológicos que plantean. El estudio adopta un enfoque cualitativo y teórico-analítico, basado en una revisión narrativa de la literatura científica internacional publicada entre 2020 y 2025, incluyendo fuentes indexadas como la *Stanford Encyclopedia of Philosophy*, *Nature*, *Neuroethics y Oxford Handbooks*, así como obras clásicas de filosofía. El análisis traza un mapa de las neurotecnologías actuales y emergentes, como las interfaces cerebro-ordenador, las neuroprótesis y las técnicas de modulación de la memoria, y examina sus implicaciones éticas, incluidas cuestiones como la privacidad mental, la identidad y la mejora humana. Los resultados ponen de relieve que las neurotecnologías no solo amplían la comprensión científica del cerebro, sino que también desafían las concepciones filosóficas tradicionales de la personalidad, la libertad y la responsabilidad moral. El estudio concluye haciendo hincapié en la urgente necesidad de contar con marcos normativos sólidos y directrices éticas que garanticen que el desarrollo tecnológico promueva la dignidad humana, la libertad cognitiva y la justicia social, en lugar de reforzar las desigualdades o comprometer la autonomía.

Palabras clave: Neurotecnologías. Neuroética. Filosofía de la neurociencia. Naturaleza humana. Interfaz cerebro-ordenador.

INTRODUCTION

The philosophy of neuroscience, as outlined in the *Stanford Encyclopedia of Philosophy* (BICKLE; MANDIK; LANDRETH, 2019), distinguishes between the philosophy of neuroscience, focused on conceptual foundations and methodological issues of neuroscience and neurophilosophy, which applies neuroscientific knowledge to traditional philosophical questions. Since Patricia Churchland's seminal work Neurophilosophy (1986), this field has sought to integrate findings from brain science with philosophical inquiry, inaugurating what has been called the "neuroscientific turn".

In recent decades, the emergence of neurotechnologies from functional neuroimaging to brain-computer interfaces (BCI) and neuroprostheses has created new possibilities for understanding and even modifying brain function. These advances have expanded the empirical basis of neuroscience and raised complex normative questions regarding mental privacy, personal identity, moral responsibility, and the very definition of what it means to be human.

Research problem despite the increasing availability of studies on neurotechnology, there is still a lack of integrative analyses that systematically connect these technological advances with the ontological and ethical questions traditionally debated in philosophy. Much of the literature remains fragmented, either emphasizing the technical aspects of neurotechnologies or discussing their ethical implications in isolation.

Guiding question how do contemporary neurotechnologies including BCI, neuroprosthetics, and memory modulation techniques challenge and reshape central philosophical debates on human nature, identity, and moral responsibility?

This article seeks to fill this gap by offering a theoretical-analytical review that maps current and emerging neurotechnologies, highlights their ethical and philosophical implications, and critically discusses their potential to transform our conception of the human condition. By situating neurotechnology within the broader framework of neuroethics and transhumanism, we aim to contribute to a more systematic understanding of how these innovations demand new regulatory and normative approaches to protect autonomy, cognitive liberty, and social justice.

2 THEORETICAL FRAMEWORK

The philosophy of neuroscience has evolved from a descriptive integration of brain science into philosophical discourse to a critical field that interrogates the ethical, ontological, and political implications of neuroscientific innovation. The so-called "neuroscientific turn", inaugurated by Churchland's *Neurophilosophy* (1986), contributed to dismantling Cartesian dualisms, reframing questions about consciousness, freedom, and moral responsibility within a naturalistic paradigm.

However, as UNESCO (2021), emphasizes in its Recommendation on the Ethics of Neurotechnology, the challenge is no longer merely theoretical: technological development is outpacing regulatory frameworks, demanding a critical and anticipatory philosophical response.

Neurotechnology including brain-computer interfaces (BCI), neuroprostheses, and memory modulation techniques reopens classical debates on personhood, autonomy, and moral responsibility. If memory contributes to the constitution of personal identity, as Locke proposed, then its artificial alteration raises profound questions about authenticity and the continuity of the self.

From a Kantian standpoint, this concern becomes normative: autonomy, the cornerstone of moral agency, requires that individuals be authors of their own maxims of action. Interventions that erase, implant, or manipulate memories risk undermining this moral authorship, threatening the very basis of responsibility.

The debate becomes even more pressing in the field of human enhancement. Julian Savulescu and colleagues (2016), argue that cognitive and moral enhancement may be not only permissible but morally obligatory if it increases well-being and reduces harm, following a utilitarian calculus aimed at maximizing collective benefit.

In contrast, Francis Fukuyama (2002), warns that radical enhancement endangers the "Factor X" the essence grounding human dignity risking a scenario where equality and the universality of rights are compromised.

A systematic comparison of these views reveals deeper normative tensions. Savulescu presumes that enhancement can be ethically justified whenever it optimizes aggregate welfare, framing technological progress as a moral project. Fukuyama (2002), conversely, highlights the risks of coercion and social stratification, arguing that enhancement could create a biologically or cognitively "augmented elite" undermining democratic equality.

These positions expose a fundamental dilemma: should society embrace a bioutilitarian vision of maximizing potential at the cost of possible new inequalities, or adopt a precautionary stance that prioritizes the preservation of a shared concept of humanity?

Recent literature highlights that this dilemma becomes even more complex with the integration of artificial intelligence into neurotechnology. Machine learning algorithms now enable BCIs to decode neural signals with increasing accuracy, but they also introduce risks of algorithmic bias, opacity, and potential misuse.

According to Yang *et al.* (2023), explainability and human oversight are crucial to prevent "black box" decisions that could affect users' autonomy, particularly in medical and military applications. Similarly, Lázaro-Muñoz *et al.* (2024) argue that ethical frameworks for BCI must incorporate fairness, accountability, and transparency (FAT) principles, ensuring that neural data processing respects human rights and avoids reinforcing social inequalities.

UNESCO's (2024), call for global governance of neurotechnology offers a mediating perspective by emphasizing principles of human dignity, cognitive liberty, and justice. Rather than accepting either technological determinism or bioconservative alarmism. UNESCO advocates a rights-based framework, proposing the recognition of "neurorights" mental privacy, psychological continuity, personal identity, as universal human rights. This perspective aligns with Kant's categorical imperative: individuals must never be reduced to mere means in technoscientific projects, but must be treated as ends in themselves, with full respect for their autonomy.

Nevertheless, critical theorists such as Byung-Chul Han (2018) and Evgeny Morozov (2020), warn that technological enthusiasm may conceal new forms of domination. Han argues that digital technologies create regimes of transparency and self-surveillance that transform freedom into compulsion, leading to what he calls "psychopolitics".

Morozov (2020), on the other hand, cautions against "technological solutionism" the belief that every social problem can be solved through technical innovation, which risks depoliticizing ethical debates and concentrating power in corporate or state actors. Incorporating these critical perspectives ensures that philosophical reflection remains alert to the socio-political consequences of neurotechnological deployment.

Finally, the convergence between neurotechnology and artificial intelligence raises further ethical complexity. BCI systems rely on machine learning algorithms capable of decoding neural signals, raising questions about transparency, algorithmic bias, and the risk of "cognitive hacking".

UNESCO (2021), explicitly warns that these risks must be mitigated through regulation ensuring human oversight and accountability, reinforcing the idea that technological progress must remain under normative control. In this sense, a robust theoretical framework must go beyond description, articulating three interdependent dimensions:

Empirical-descriptive: mapping emerging neurotechnologies and their applications;

Normative-ethical: evaluating them through principles such as autonomy, beneficence, justice, and neurorights; Philosophical-critical: systematically comparing competing views, such as

Savulescu's utilitarian optimism and Fukuyama's bioconservatism, to reveal their assumptions and anticipate the sociopolitical consequences of large-scale adoption.

By integrating these dimensions, this article positions the philosophy of neuroscience as a normative compass for the neurotechnological era, ensuring that innovation remains consistent with human dignity, freedom, and global justice.

2.1 COMMUNICATION AND CONNECTION

The use of a BCI that allows direct communication and connection between our brains and an online network is one of the potential uses that raises the most ethical concerns. There are large private companies already working on this. There is at least one Big Tech company that claims to be developing the first neural implant that will allow people to control their

computer or cell phone from wherever they are, just by thinking about it, using only their brain activity.

The military use of BMIs also raises major ethical concerns. DARPA4 makes it clear on its website that it envisions a future in which machines would not only be tools that execute rules programmed by humans, but rather, in which machines function more as colleagues than as tools, and to this end, DARPA5 research and development of machine-human symbiosis aims to partner with machines.

Miguel Nicolelis (2020, p. 293) "proposes something different, what he calls a shared *brain/machine interface, or Brainet*". For him, a brainet is a distributed organic computer composed of multiple individual brains that synchronize, in the analog domain, by an external signal, such as light, sound, language, chemistry, radio or electromagnetic waves, and is capable of producing emerging social behaviors.

This organic computer is capable of something unique in the universe, namely: transforming information provided by the universe into knowledge to be passed on to future generations so that they may continue the most important existential mission of our species, which is the construction of its own universe.

Nicolelis tested the brain-to-brain version of brainet on mice, with a direct connection between their cortices, and the results showed that the mice learned to exchange simple binary messages.

Subsequently, another version was tested in 2014 with a shared brain/machine interface, where a computer mixed the electrical activity generated simultaneously by three individual monkey brains, so that in this brainet the only way to move the virtual arm to the target would be if at least two of the three participants synchronized the electrical activity produced collectively by their motor cortices.

3. METHODOLOGY

This study is characterized as a qualitative and theoretical-analytical narrative review, chosen for its ability to integrate conceptual, normative, and empirical perspectives and to allow a critical dialogue between neuroscience, philosophy, and ethics. Unlike systematic reviews, which focus on exhaustively mapping empirical evidence to answer narrowly defined questions, the narrative approach enables a more comprehensive examination of theoretical

debates, historical developments, and normative implications which are central to the objectives of this research.

The literature review was conducted between January and July 2025 in the following indexed databases and repositories: PubMed, Scopus, Web of Science, PhilPapers, SpringerLink, Oxford Academic, and Stanford Encyclopedia of Philosophy. Additional sources were identified through citation chaining and consultation of relevant books from leading publishers (MIT Press, Oxford University Press, Cambridge University Press).

Search terms were structured in English, Spanish, and Portuguese to broaden coverage and included combinations such as: neurotechnology, ethics, brain-computer interface OR BCI, neuroprosthetics, philosophy, memory modulation, memory editing, cognitive enhancement, neuroethics, transhumanism, human nature.

Inclusion criteria: peer-reviewed articles, book chapters, and conference papers published between 2020 and 2025, with a focus on neurotechnology, neuroethics, transhumanism, or the philosophy of neuroscience. Conceptual, empirical, and normative works that explicitly address ethical, ontological, or philosophical questions related to neurotechnological innovation. Publications in English, Spanish, or Portuguese.

Exclusion criteria: articles prior to 2020 (unless classic or foundational references necessary for theoretical contextualization). Studies focusing exclusively on technical or clinical aspects without philosophical or ethical analysis. Non-peer-reviewed sources without academic rigor, such as blogs, opinion pieces, or non-indexed materials.

The selected literature was coded according to three axes: a) type of neurotechnology (recording, modulation, neuroprosthetics, BCI), b) philosophical/ethical issue addressed (mental privacy, identity, enhancement, regulation), and c) normative implications (individual autonomy, justice, risk-benefit assessment). A thematic synthesis was then conducted, identifying convergences, tensions, and gaps in the literature, which informed the structuring of the discussion and final considerations.

4. DISCUSSIONS AND RESULTS

The results of this narrative review highlight that neurotechnologies encompassing brain-computer interfaces (BCI), neuroprosthetics, neuropharmaceuticals, and memory modulation techniques represent one of the most disruptive technological frontiers of the 21st century, with the potential to transform not only medical practice but also our understanding of the human condition.

The analysis of the literature (2020-2025) reveals four key thematic axes: 1) therapeutic applications and cognitive enhancement, 2) risks to mental privacy and autonomy, 3) ontological implications for identity and authenticity, and 4) sociopolitical and normative challenges for governance.

4.1 THERAPEUTIC APPLICATIONS AND COGNITIVE ENHANCEMENT: PROMISE AND CONTROVERSY

From a therapeutic perspective, neurotechnologies have yielded significant benefits. Neuroprosthetics such as cochlear implants and neuromotor prostheses have restored sensory and motor functions to individuals with severe disabilities (ROMMELFANGER *et al.*, 2022). Advances in deep brain stimulation (DBS) and neuropharmacology have offered alternatives for treating Parkinson's disease, severe depression, and Alzheimer's disease.

These applications are widely celebrated as examples of the emancipatory potential of technoscience, aligning with the principle of beneficence in bioethics. However, the literature reveals growing interest in cognitive enhancement, that is, the use of neurotechnologies not only to restore lost functions but to amplify normal capacitie, memory, attention, emotional regulation, beyond what is considered species-typical. Here, the debate becomes more polarized.

Savulescu *et al.* (2016) argue that enhancement can be morally obligatory when it increases well-being and reduces harm, invoking a utilitarian logic that seeks to maximize global benefits. Conversely, critics such as Fukuyama and Habermas (noted in transhumanism literature) warn that radical enhancement may undermine the moral equality that underpins human rights, generating new forms of stratification between "enhanced" and "unenhanced" individuals.

The tension between these perspectives suggests that cognitive enhancement cannot be evaluated solely in biomedical terms. It requires a broader socioethical assessment that considers distributive justice (who will have access?), autonomy (are individuals truly free to refuse enhancement?), and long-term societal effects (will enhancement create pressure for normalization, coercing individuals into upgrading themselves to remain competitive?).

4.2 MENTAL PRIVACY, COGNITIVE LIBERTY, AND ETHICAL RISKS

One of the most consistent findings in the reviewed literature is the urgency of protecting mental privacy and cognitive liberty. Ienca and Andorno (2017) propose a set of

neurorights that include the right to mental privacy, mental integrity, and psychological continuity.

The dual-use nature of these technologies is particularly concerning. While BCIs could enable telepathic-like communication or allow individuals with paralysis to interact with their environment, the same devices could be exploited for surveillance or behavioral manipulation. The risk is compounded by the involvement of Big Tech corporations and military agencies, which may prioritize commercial or strategic interests over individual rights.

The literature calls for urgent international agreements to establish clear boundaries for the collection, storage, and use of brain data, drawing inspiration from data protection frameworks such as the GDPR but going beyond them to cover the neurocognitive dimension.

4.3 IDENTITY, AUTHENTICITY, AND THE SELF IN THE AGE OF NEUROTECHNOLOGY

Another significant result concerns the impact of neurotechnologies on personal identity and the authenticity of the self. Memory modification techniques (MMT) whether through pharmacological agents or optogenetic interventions offer the possibility of erasing traumatic memories or implanting new ones (YUSTE *et al.*, 2017). While this can be therapeutic for patients with PTSD, it raises questions about whether a self with altered memories is still the "same" self.

Philosophically, this debate has two main axes. From an essentialist perspective, authenticity is linked to fidelity to one's own life history; erasing memories would therefore compromise personal integrity. From an existentialist perspective, authenticity can mean actively shaping one's own existence in this view, the ability to edit memories might represent an exercise of freedom and self-creation (KANT, 2013). The challenge is to develop ethical criteria that distinguish between legitimate therapeutic use and coercive or manipulative interventions.

Moreover, brain-to-brain interfaces (Brainets) tested by Nicolelis (2020), introduce a collective dimension to identity: if multiple brains can be connected to produce emergent behaviors, where does individual responsibility lie? Could we speak of distributed agency or collective consciousness? These questions demand a re-examination of legal and moral frameworks, which traditionally assume that responsibility and intention are attributes of individual agents.

4.4 GOVERNANCE, REGULATION, AND THE NEED FOR NORMATIVE FRAMEWORKS

The literature converges on the diagnosis that technological development is outpacing regulatory capacity. UNESCO's (2024) Recommendation on the Ethics of Neurotechnology calls for global governance mechanisms to guarantee that neurotechnological innovation respects human rights, equity, and sustainability. The proposal of neurorights currently being implemented in Chile's constitutional reform represents a pioneering step, but international harmonization is still lacking.

A critical point emerging from the analysis is that regulation must strike a delicate balance: it should prevent abuses (e.g., unauthorized mind-reading, neuro-manipulation for coercive purposes) without stifling legitimate innovation that could benefit society. This requires a multi-stakeholder approach involving scientists, ethicists, policymakers, and civil society. The creation of ethical impact assessments, similar to environmental impact studies, has been proposed as a tool to anticipate and mitigate risks before large-scale implementation.

4.5 TOWARD AN INTEGRATIVE AND CRITICAL PERSPECTIVE

Taken together, these findings suggest that neurotechnologies are not neutral tools but transformative agents that reconfigure the human-nature-technology triad. The results support the view that we are already in a proto-transhuman era, where the distinction between therapy and enhancement, natural and artificial, human and machine becomes increasingly blurred.

From a critical-theoretical standpoint, the challenge is to avoid two symmetrical dangers: technological determinism, which sees innovation as an unstoppable force that must simply be accepted, and technological pessimism, which demonizes any attempt to transcend biological limitations. A balanced approach recognizes both the emancipatory potential and the risks of dehumanization.

This article's contribution lies precisely in articulating this middle path: by integrating neurophilosophical, neuroethical, and sociopolitical dimensions, it highlights that the future of neurotechnology must be guided by principles of autonomy, justice, and solidarity.

Ethical deliberation must be proactive, not reactive, anticipating scenarios before technologies are fully deployed. In this sense, philosophy of neuroscience can function as a normative compass, helping societies to navigate the uncertain territory between utopia and dystopia.

FINAL CONSIDERATIONS

Today more than ever, science, technoscience, and the most diverse forms of technology must return to the reflective cultivation of human wisdom, in its diversity and civilizational legacies, which include the arts, religions, and the philosophical contributions accumulated over centuries and millennia.

There are several scientists, philosophers, and ethicists working to promote transhumanism, as evidenced by the creation of the World Transhumanist Association (WTA), Humanity Plus (H+), and transnational foundations and NGOs that stimulate this discussion, combined with scientific research programs and public policies around technological singularity, superintelligence, and so-called strong AI.

Once again, extremes on both sides of the spectrum between the most conservative and the most progressive can be avoided. Therefore, we believe it is desirable to always maintain a moderate position between the extreme positions of those who demonize technologies and those who are overly enthusiastic about technological innovations to transcend the so-called human condition.

We believe that the most felicitous formulation of this tension between what we are as conditioned and genetically programmed beings and what we can be through our own reflective choices, including the improvement of neurotechnologies and new AI technologies, is expressed by the philosopher Ernst Tugendhat (2012), when he insists that we are not made of rigid wire. In a sense, we are certainly wired, in that we are a complex result of various systems and microsystems of neurobiological and sociocultural conditioning, but, unlike bees, dolphins, and chimpanzees, we are flexible, malleable, reflective, and truly unpredictable, in that we can reject a given natural or sociocultural condition or environment and can transcend such conditioning and overcome the most deeply rooted traditions or behavioral codifications, in addition to always being able to review our own beliefs and reflective judgments. There are certainly natural limits, but it is precisely these that are being challenged by new technologies, whose regulation seeks to establish normative limits.

Future research in order to deepen the philosophical and ethical understanding of neurotechnological innovation, future research should: conduct comparative empirical studies on public perceptions of neurorights and mental privacy across different cultural and legal contexts; explore longitudinal impacts of cognitive enhancement interventions on identity formation, autonomy, and social stratification; investigate algorithmic transparency and

accountability in brain-computer interfaces, proposing measurable criteria for explainability and human oversight; map emerging ethical dilemmas arising from hybridization between neurotechnology and AI, including risks of cognitive hacking and collective decision-making in brain networks (brainets).

Recommendations for public policy at the policy level, it is crucial to: develop internationally harmonized regulatory frameworks, inspired by UNESCO's recommendation on the ethics of neurotechnology, to protect mental privacy, autonomy, and personal identity; encourage multi-stakeholder participation (scientists, ethicists, policymakers, civil society) in the creation of neurorights charters and ethical impact assessments; promote equitable access to neurotechnological therapies and enhancements, preventing the creation of new social inequalities; support interdisciplinary research funding and the integration of neuroethics into medical, technological, and legal education.

By combining philosophical reflection, empirical research, and proactive governance, society can ensure that neurotechnological development remains aligned with human dignity, cognitive liberty, and social justice. Ethical deliberation must be anticipatory, not merely reactive, guiding innovation before its large-scale deployment. In this sense, the philosophy of neuroscience can function as a normative compass, enabling humanity to navigate the complex landscape between utopia and dystopia with prudence, justice, and responsibility.

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