Emerging Uses of Neurotechnology

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Abbreviations

5G	Fifth generation mobile network
Convention 108	Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data (CETS No. 108)
Convention 108+	Amending protocol to the Convention for the Protection of Individuals with Regard to the Processing of Personal Data, adopted by the Committee of Ministers at its 128th Session in Elsinore on 18 May 2018
EEG	Electroencephalography
EU AI Act	Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828
GDPR	Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC
IEEE	Institute of Electrical and Electronics Engineers
ICO	Information Commissioner's Office of the United Kingdom
OECD	Organization for Economic Co-operation and Development
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children’s Fund
USD	United States dollar

Disclaimer

This literature review was completed by Verónica Arroyo, a privacy lawyer and policy advisor for emerging technology, and commissioned by the Office of the Information and Privacy Commissioner of Ontario (IPC). The report synthesizes literature on emerging uses of neurotechnology with information available until November 2024. The views reflected within the report are not necessarily those of the IPC. The report is for informational purposes only; should not be relied upon as a substitute for the legislation itself or as legal advice; and does not bind the IPC, which may be called upon to independently investigate and decide upon an individual complaint or appeal based on the specific facts and unique circumstances of a given case. For the most up-to-date version of this report, visit the IPC's website at **www.ipc.on.ca**.

1. Executive summary

This literature review informs the Office of the Information and Privacy Commissioner of Ontario (IPC) about the current state of neurotechnology, its implications, and its possible evolution in the following years. It synthesizes findings from academic research, policy reports, legal documents, and government publications. The review aims to provide a comprehensive understanding of neurotechnology's opportunities and challenges, offering guidance on legal and ethical considerations.

This document is organized into eight parts, guiding readers through a comprehensive exploration of neurotechnology. After an introductory overview, part three summarizes key findings, setting a foundation for understanding the topic. Part four examines the adoption of neurotechnologies in health, employment, and law enforcement contexts. Parts five and six delve into these technologies' legal and ethical issues. Part seven highlights recent legislative and policy developments, while part eight discusses future trends and potential advancements. Finally, part nine concludes with reflections on the broader implications of neurotechnology for individuals and society.

Some key highlights of this review are:

- **Lack of consensus on definitions:** No universally accepted definition of neurotechnology or neurodata complicates classification and regulatory responses.
- **Opportunities and challenges:** While neurotechnologies offer significant benefits in health, they also raise technical, legal, ethical, and socio-economic challenges.
- **Data privacy risks:** Neurotechnologies process neurodata that can be linked to an individual becoming personal data. Besides the physiological information it possesses, the worry of scholars lies in the possibility of inferring highly sensitive information such as personality traits, sexual orientation, cognitive performance, and mental states without the individual being aware due to the data being intrinsic to the individual. This poses unique privacy and intimacy risks, including unauthorized access, profiling, and potential misuse in health and employment. On top of that, neurotechnologies hold the potential to impact the individual's identity and autonomy, weakening the obtaining of informed free consent in the use of neurotechnologies.
- **Legal responses:** Scholarly perspectives on addressing neurotechnological challenges vary — some advocate for creating new rights (e.g., cognitive liberty or neurorights), others recommend adapting existing laws, while some argue no new rights are needed.
- **Ethical issues:** Concerns include threats to identity and authenticity, unequal access, and risks of stigmatization, particularly for vulnerable populations like Indigenous peoples, neurodiverse individuals, and those with mental health conditions.
- **Emerging trends:** In the coming years, neurotechnologies are expected to improve in accuracy, reduce tissue damage, enhance brain-computer interfaces, and develop augmentative capabilities, raising new ethical and legal questions.

2. Introduction

Neurotechnology has both positive and negative effects that create opportunities and challenges for the individual and society. Its implications have drawn substantial attention from ethicists, lawyers, policymakers, and developers, sparking debates across various forums. This literature review seeks to summarize the current debate surrounding the development and use of neurotechnologies, the challenges they pose, and potential solutions. In that sense, it compiles and organizes information from academic and non-academic sources, legal documents, and policy documents.

The literature review is organized into eight sections. Following this introduction, part three provides an overview of the most important findings to establish a foundation for neurotechnology. Part four explores the neurotechnologies utilized in the contexts of health, employment, and law enforcement. Parts five and six examine the associated legal and ethical issues, respectively. Part seven highlights recent legislative and policy developments, along with predictions for the future of this field. Finally, part eight reflects on what the future of neurotechnologies may look like, and part nine synthesizes the review highlighting the need for a balanced approach.

3. Summary of conclusions

3.1 What is neurotechnology?

3.1.1 Definition

There is no universally accepted definition of neurotechnology. While in most of the literature, neurotechnology refers to devices, for some of them, which follow the OECD definition, it also includes procedures.[1][2][3][4][5][6] In a recent paper, Bertoni and Ienca suggest that neurotechnology should also encompass tools, systems, and algorithms.[7]

1 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

2 Ministère de l'Enseignement supérieur et de la Recherche (2022). Charte de développement responsable des neurotechnologies. https://www.enseignementsup-recherche.gouv.fr/fr/charte-de-developpement-responsable-des-neurotechnologies-87964

3 Information Commissioner's Office (2023). ICO tech futures: Neurotechnology. p. 8. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

4 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 6. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

5 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 19. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

6 Global Privacy Assembly (2024, November). Resolution on Principles regarding the Processing of Personal Information in Neuroscience and Neurotechnology. 46th Closed Session of the Global Privacy Assembly. https://globalprivacyassembly.org/wp-content/uploads/2024/11/Resolution-on-Neurotechnologies.pdf

7 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 2. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

Neurotechnology is used for a wide range of activities. Although individual authors define these activities differently, overall, the activities that appear most in literature are to access, understand, explore, monitor, infer, evaluate, influence, manipulate, modulate, modify, emulate, and record data.

To perform these tasks, neurotechnologies require data from specific sources. Some authors broadly describe the target of neurotechnology as the "nervous system" or "neural system."[8] [9] [10] [11] [12] [13] [14] [15] [16] Within this group, the IEEE Brain specifies that the target is the central nervous system,[17] the peripheral nervous system, or the autonomic nervous system. For others, like Ienca and UNICEF the target is only the brain.[18] [19] This distinction is significant because some technologies like wristbands get information from the peripheral system. Other devices like tablet computers, smartphones, and watches will also process the information but in an indirect way. Additionally, biometric technologies can infer data, which the ICO classifies as second-order inferences.[20]

3.2.1 Classification

The lack of precision in the definition of neurotechnologies also complicates their classification. As noted by the Regulatory Horizon Council, there is no consensus on how

8 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

9 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 14. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

10 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 13. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

11 Human Rights Council (2022). Resolution A/HRC/RES/51/3. Neurotechnology and Human Rights. https://undocs.org/A/HRC/RES/51/3

12 Ministère de l'Enseignement supérieur et de la Recherche (2022). Charte de développement responsable des neurotechnologies. https://www.enseignementsup-recherche.gouv.fr/fr/charte-de-developpement-responsable-des-neurotechnologies-87964

13 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 6. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

14 Genser, J., Damianos, S., & Yuste, R. (2024). Safeguarding Brain Data: Assessing the Privacy Practices of Consumer Neurotechnology Companies. p. 6. https://www.perseus-strategies.com/wp-content/uploads/2024/04/FINAL_Consumer_Neurotechnology_Report_Neurorights_Foundation_April-1.pdf

15 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 2. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

16 Information Commissioner's Office (2024). Mental privacy and Integrity. p. 19. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

17 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 14. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

18 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 9. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

19 UNICEF (2024). Neurotechnology and Children. p. 7. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

20 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 8. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

to best classify neurotechnologies and the categories are often blurred.[21] These can be purpose-based, invasiveness-based,[22] [23] or risk-based for medical neurotechnologies.[24]

From a purpose-based perspective which appears to be the most commonly adopted approach, several agreed-upon categories emerge:

- **Neuroimaging technologies** are used to access and monitor the structure and function of the nervous system through different techniques.[25] Notable examples of these technologies are electroencephalography, a functional magnetic resonance imaging that uses blood flow to scan brain activity, or functional near-infrared spectroscopy that uses uses infrared signals.
- **Neuroprostheses** are designed "to substitute or restore lost sensory, motor, or cognitive functions."[26]
- **Neuromodulation and neurostimulation technologies** aim to "activate and regulate neuronal activity" using electrical or magnetic signals.[27] While neuromodulation seeks long-term effects, neurostimulation aims for short-term ones.[28] A common example of neurostimulation is deep brain stimulation, which has been used to treat motor symptoms of neurological disorders such as Parkinson's disease.[29] Additionally, neurostimulation, paired with other intervention, can have more enduring effects such as longitudinal neurostimulation used to improve working memory in older adults or studied to treat patients with refractory chronic low back pain associated with multifidus muscle dysfunction.[30] [31]

21 Regulatory Horizon Council (2022). Neurotechnology Regulation. pp. 16,19, 20. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

22 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 10. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

23 European Data Protection Supervisor and Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 2. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

24 U.S. Food & Drug Administration (2021). Neurological Devices. https://www.fda.gov/medical-devices/products-and-medical-procedures/neurological-devices

25 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 18. https://doi.org/10.54678/QNKB6229

26 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 15. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

27 UNICEF (2024). Neurotechnology and Children. p. 8. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

28 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 10. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

29 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 17. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

30 Jones KT, Stephens JA, Alam M, Bikson M, Berryhill ME (2015). Longitudinal Neurostimulation in Older Adults Improves Working Memory. https://doi.org/10.1371/journal.pone.0129751

31 Gilligan, C., Volschenk, W., Russo, M., Green, M., Gilmore, C., Mehta, V., & Eldabe, S. (2024). Five-Year Longitudinal Follow-up of Restorative Neurostimulation Shows Durability of Effectiveness in Patients With Refractory Chronic Low Back Pain Associated With Multifidus Muscle Dysfunction. (2024). Neuromodulation, Volume 27, Issue 5, pp. 930-943. https://www.neuromodulationjournal.org/article/S1094-7159(24)00055-2/fulltext

- **Neurointerfaces** enable control over applications or devices.[32] A classical example is brain machine interfaces also known as brain computer interface. These technologies follow a four-step cycle which includes an input, a digitalization, a processing, and a command sent to a device.[33] [34]

Neurotechnologies can also provide neurofeedback also called closed loop systems, offering real-time information back to the individual, which enhances neuromodulation, neurostimulation, and neurointerface functions.[35] [36] This feedback can come as the brain's electrical waves or as insights in an external device or wearable.[37] [38] Additionally, these types of neurotechnologies can be combined to create a brain-to-brain interface or interaction to send information from a sender-brain to a receiver brain.[39] [40] [41] Furthermore, all of these technologies can see an inflection point with the integration of artificial intelligence, which can optimize a large-scale analysis of neuro functions and predict instructions to neurotechnology devices.[42] [43]

32 European Data Protection Supervisor, andAgencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. pp. 7, 8. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

33 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 17. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

34 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 7. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

35 European Data Protection Supervisor, and Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. pp. 7, 8. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

36 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 7. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

37 UNICEF (2024). Neurotechnology and Children. p. 8. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

38 Regulatory Horizon Council (2022). Neurotechnology Regulation. pp. 19, 20. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

39 UNICEF: "Such BCIs Have Allowed Three People, in Different Rooms, to Collaborate and Solve a Task using Direct Brain-to-Brain Communication as their Only Mode of Interaction." UNICEF (2024). Neurotechnology and Children. p. 10. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

40 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 6. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

41 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 8. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

42 UNICEF (2024). Neurotechnology and Children. p. 12. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

43 Tang, J., LeBel, A., Jain, S., & Huth, A. G. (2023, May 1). Semantic Reconstruction of Continuous Language from Non-Invasive Brain Recordings. Nature Neuroscience. Retrieved February 22, 2024, https://www.nature.com/articles/s41593-023-01304-9

3.2 What is neurodata?

3.2.1 Definition

Neurotechnologies process a new type of data, called "neurodata."[44] Even if there is no consensus on what constitutes neurodata,[45] Neurodata is generally understood to encompass information related to the structure and function of the brain and peripheral nervous system.[46] [47] [48] [49] [50] This means neurodata can be extensive, diverse,[51] and inherently involuntary and intrinsic of the human being[52] making it highly sensitive information.[53] Also, for better processing, this data can be combined with other data, like voice recordings, activity logs, neuropsychological evaluations, and more.[54]

An important aspect of defining neurodata is whether it can be linked or identify a specific individual. Some definitions imply that neurodata is linked to a person,[55] while others make the difference between neurodata and personal neuro/brain data[56] [57] or explicitly mentions

44 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 7. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

45 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 8. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

46 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

47 Ministère de l'Enseignement supérieur et de la Recherche (2022). Charte de développement responsable des neurotechnologies. https://www.enseignementsup-recherche.gouv.fr/fr/charte-de-developpement-responsable-des-neurotechnologies-87964

48 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 21. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

49 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 19. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

50 European Data Protection Supervisor, and Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 6. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

51 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age ofNeuroscience and Neurotechnology. BioMed Central. p. 12. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

52 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 18. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

53 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 24. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

54 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 5. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

55 Global Privacy Assembly (2024, November). Resolution on Principles Regarding the Processing of Personal Information in Neuroscience and Neurotechnology. 46th Closed Session of the Global Privacy Assembly. https://globalprivacyassembly.org/wp-content/uploads/2024/11/Resolution-on-Neurotechnologies.pdf

56 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

57 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 3. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

that it is data of an identified or identifiable individual.[58] This distinction is significant because, as of 2021, identifying individuals using neurodata was only possible in controlled lab environments. However, experts anticipate that this capability will become more feasible in the near future.[59]

Another factor influencing the composition of neurodata and its potential to identify individuals is neuroplasticity. Neurodata captures the temporal dynamics of neural activity, which can change in response to experiences and external stimuli.[60] The consequences of this factor are analyzed in the legal issues section.

3.2.2 What kind of information is included?

Neurodata contains information about the biomarkers that help us to understand neurological disorders and other health issues.[61] Additionally, scholars such as Ienca, and Bertoni affirm that "neural data possess propositional and semantic value." This idea sounds possible because "the prospect of decoding or modifying neural activity implies the possibility of decoding or modifying cognitive and affective processes." In other words, neurodata holds information about mental states that goes beyond sensory or motor inputs and outputs, encompassing cognitive, affective, conative, perceptual, and sensory states.[62] Greenberg et al. similarly highlighted the potential to infer biological and cognitive states, such as moods and intentions, from neurodata.[63]

In previous research, Ienca noted that by 2021 algorithmic techniques in laboratory settings were capable of predicting a person's memories from brain data and even detecting hidden intentions, preferences, and dreams.[64] Nevertheless, the mass feasibility of obtaining persons' thoughts remains unconfirmed. In 2021, Ienca stated that neurotechnologies were not able to decode thoughts, meaning that they "are not capable of providing a full, granular, real-time and propositionally or experientially describable account of the neural patterns of specific mental processes such as memories or emotions."[65] Similarly, Greenberg et al. in the same year, said that getting the individual's thoughts is "still in the

58 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 19. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

59 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 9 https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

60 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 6, 7. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

61 Ienca, M. (202). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 22. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

62 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 5-7. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

63 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 9. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

64 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 23. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

65 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. pp. 25, 26. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

early research phases and could be decades from fruition, or perhaps never emerge."[66] In 2023, the ICO confirmed that while the long-term goals of neurotechnologies include decoding memories, sounds, thoughts, and mental images, these remain largely theoretical and confined to lab-based approaches.[67] The ICO also mentioned that many parties and scholars have concerns about how accurate algorithms are to detect emotional cues.[68]

On a side note, the information that neurodata could provide can also be obtained through biometric data processing. This type of data is being proposed to be called "cognitive biometric data" and is analyzed in the legal issues section.[69] [70]

3.3 Is it a promising area?

3.3.1 Increasing innovations

Although neurotechnologies may seem novel, their origins date back to the late 19th century. The first major development on this topic dates back to 1878 when Richard Canton discovered electrical signals in an animal's brain.[71] Subsequently, in 1924 Hans Berger recorded the first EEG in a human.[72] A further advancement took place in 1969 when a single neuron of a monkey was connected to an external device. Several years later, in 1973, Jaques Vidal coined the term "brain-computer communication" and created a prototype of the direct communication between the human brain and the computer. Then in 1988, this idea was proved for the first time at the University of Skopje.[73] Similar advancements occurred with other neurotechnologies; during the 1990s, often referred to as the "decade of the brain," as the imaging and behavioral studies increased.[74]

66 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 9. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

67 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 9. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

68 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 18. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

69 Bertoni, E., & Ienca, M. (2024). The privacy and data protection implication of the use of neurotechnology and neural data from the perspective of Convention 108. p. 6. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

70 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 7. https://unesdoc.unesco.org/ark:/48223/pf0000391074

71 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age ofNeuroscience and Neurotechnology. BioMed Central. p. 2. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

72 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 11. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

73 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 16. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

74 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 2. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

Recent innovation in the neurotechnology landscape targets both medical and non-medical uses. There have been achievements that enable individuals to regain the ability to walk,[75] speak,[76] and enable quadriplegic patients to write emails, watch videos, and use tablets using only their brain activity.[77] In the non-medical realm, researchers have decoded a Pink Floyd song by analyzing neural activity with generative AI, reconstructed mental images with 90 per cent accuracy for seen images and 75 per cent accuracy for imagined images, and decoded speech with 72.5 per cent accuracy.[78] Concurrently, companies like Apple and Samsung are integrating neurogadgets such as headsets, as accessory options in their devices. These non-invasive devices are predicted to replace keyboards, touch screen, mouse, and voice command devices.[79]

These recent advancements are attributable to several factors, including reductions in hardware costs that have made sensors more affordable, lightweight, efficient, and portable.[80] [81] Moreover, adjacent technologies such as artificial intelligence, 5G, wireless connectivity, and cloud storage have also evolved rapidly. All this is supported by a neurotechnology ecosystem with little regulation and an appetite for datafication.[82]

3.3.2 How is the market developing?

Recent advancements in neurotechnology innovations are reflected in the evolution of its market. Predictions regarding the market's value have increased significantly in recent years. In 2023, the Information Commissioner's Office reported that the U.K.'s Regulatory Horizon Council was predicting a value of $17.1 billion USD globally by 2026.[83] In the same year, UNESCO projected that the market for neurotechnology devices would grow to 24.4 billion by 2027.[84] In 2024, the ICO raised its estimate for the market value to $18 billion

75 UNESCO (2023). Unveiling the Neurotechnology Landscape: Scientific Advancements Innovations and Major Trends. p. 22. https://doi.org/10.54678/OCBM4164

76 Genser, J., Damianos, S., & Yuste, R. (2024). Safeguarding Brain Data: Assessing the Privacy Practices of Consumer Neurotechnology Companies. p. 7. https://www.perseus-strategies.com/wp-content/uploads/2024/04/FINAL_Consumer_Neurotechnology_Report_Neurorights_Foundation_April-1.pdf

77 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 16. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

78 Genser, J., Damianos, S., & Yuste, R. (2024). Safeguarding Brain Data: Assessing the Privacy Practices of Consumer Neurotechnology Companies. pp. 7, 8. https://www.perseus-strategies.com/wp-content/uploads/2024/04/FINAL_Consumer_Neurotechnology_Report_Neurorights_Foundation_April-1.pdf

79 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 20. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

80 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 20. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

81 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 9. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

82 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 20. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

83 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 24. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

84 UNESCO (2023). Unveiling the Neurotechnology Landscape: Scientific Advancements Innovations and Major Trends. p. 26. https://doi.org/10.54678/OCBM4164

USD ($14 billion GBP) by 2026.[85] Some of this value comes from government investments. UNESCO notes that from 2013 to 2023, more than $6 billion USD has been allocated from government investments.[86]

In terms of geographical distribution, the United States leads significantly in the number of neurotechnology companies, the generation of neuroscience knowledge, and IP5 patents[87] in neurotechnology.[88] [89] Other countries like the United Kingdom, Germany, China, Korea, Japan, France, the Netherlands, Australia, and Canada are also contributing to market developments. In Canada, for instance, according to the ICO, there are approximately 34 firms.[90] In Ontario, the Ontario Brain Institute estimates there are 53 companies involved in producing neurotechnology devices, developing software, and providing therapeutic services.[91] In March 2023, there was news about $38.8 million USD in funding from the Government of Canada to support brain health research.[92] The ICO estimates that public investments in Canada from 2011 to 2019 amounted to $171 million USD.[93]

3.4 The benefits and risks

The most significant benefits of neurotechnologies have been observed in the medical sector, according to the majority of authors in the field. By 2017, neurotechnologies were recognized as a tool to improve the well-being of patients and as a new diagnostic and preventive tool.[94] They were anticipated to transform the treatment of brain injuries, including paralysis, epilepsy, and schizophrenia.[95] Later in 2019, neurotechnologies were recognized to hold promise for human health and innovation promoting economic growth according to the OECD.[96] As of writing, these benefits also encompass increased

85 Information Commissioner's Office (2024). Mental Privacy and Integrity. p. 19. https://ico.org.uk/media/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/tech-horizons-report-1-0.pdf

86 UNESCO (2023). Unveiling the Neurotechnology Landscape: Scientific Advancements Innovations and Major Trends. p. 26. https://doi.org/10.54678/OCBM4164

87 IP5 patents means patents registered in the five largest intellectual property offices in the world, which include the European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the National Intellectual Property Administration of the People's Republic of China and the United States Patent and Trademark Office. Five IP offices (n.d.) https://www.fiveipoffices.org/home

88 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 25. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

89 UNESCO (2023). Unveiling the Neurotechnology Landscape: Scientific Advancements Innovations and Major Trends. pp. 18, 19, 55. https://doi.org/10.54678/OCBM4164

90 ICO warns that there is limited data available on the number of private neurotechnology companies and used FactSet to make estimates on the number of companies in Canada and in other countries. Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. pp. 25-26. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

91 Ontario Brain Institute. Portfolio Companies. https://braininstitute.ca/portfolio-companies

92 UNESCO (2023). Unveiling the neurotechnology landscape: Scientific Advancements Innovations and Major Trends. p. 26. https://doi.org/10.54678/OCBM4164

93 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 26. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

94 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 2. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

95 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologies and AI. Nature. p. 2. https://www.nature.com/articles/551159a

96 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

accessibility for people with disabilities alongside a growing scientific understanding of neural systems that could foster further innovation and economic development.[97]

Despite the advantages, significant risks accompany the potential of neurotechnologies. These concerns relate to human rights and freedoms, the medical nature of the technology, and the potential for misuse.[98] [99] [100] One major issue is privacy as individuals do not have direct control of the information being processed. This lack of control could lead to the unintentional revelation of private thoughts and emotions that a person may never express publicly,[101] [102] or even result in self-incrimination.[103] Even more worrisome, it can reveal information that the person was never aware of.[104] Additionally, neurostimulation or neuromodulation may impair a person's ability to assess and make decisions about their private information.[105] The inherent capacity to collect and process vast amounts of detailed data further exacerbates these privacy concerns.[106]

The literature also warns about the risk of perpetuating social and systemic inequalities.[107] [108] [109] Roda cautions that neurodata can be used as a tool for discrimination by employers and insurance companies.[110] Moreover, the Panel for the Future of Science and Technology noted that algorithmic bias has been present in the practice of EEG with neurofeedback,[111]

97 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 6. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

98 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 1. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

99 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

100 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical challenges. p. 21. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

101 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 13. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

102 Roda, C. (2024, July 3). Mental Privacy and Integrity. https://iapp.org/news/a/mental-privacy-and-integrity

103 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 25. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

104 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 18. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

105 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 21. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

106 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 6. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

107 The Organisation for Economic Co-operation and Development (OECD) (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

108 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologiesand AI. Nature. p. 2. https://www.nature.com/articles/551159a

109 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 20. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

110 Roda, C. (2024, July 3). Mental Privacy and Integrity. https://iapp.org/news/a/mental-privacy-and-integrity

111 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 8. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

which could jeopardize neurodivergent individuals if neurotechnology systems are trained solely on neuro-normative patterns.[112]

What is more, the use of neurotechnologies as a means to surveil and monitor mental states can have a chilling effect on the employee. Greenberg et al. express concerns about this situation in the workplace with the use of management algorithms; in such situations, employees may experience decreased morale and altered behavior, and these technologies could also potentially affect union organization efforts.[113]

On a health-related note, the use of neurotechnologies can raise problems related to personal identity and psychology. According to Greenberg et al., researchers have seen that patients may question who the author of their psychological states is, whether themselves or the brain-computer interface.[114] Similarly, deep brain stimulation can also have side effects like any other surgical procedure to implant a neurotechnology device.[115] [116] The Panel for the Future of Science and Technology outlines four main groups of risks perioperative (e.g., seizures, hemorrhages), postoperative (e.g., hematoma, behavioral changes), technical (e.g., electrode failure, malfunctioning of pulse generator) and stimulation-induced side effects (e.g., dysarthria, confusion).[117] These concerns are particularly pronounced when considering children whose brains are more vulnerable.[118]

3.5 Challenges

Neurotechnologies also present a myriad of challenges and questions for individuals and society as a whole. These include:

- technical aspects
- accuracy problems
- legal and ethical questions
- assessment problems
- socio-economic factors
- cultural and ethnic factors

112 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 19. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

113 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. pp. 1, 20. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

114 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the connected mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 19. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

115 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 19. https://doi.org/10.54678/QNKB6229

116 Roda, C. (2024, July 3). Mental Privacy and Integrity. https://iapp.org/news/a/mental-privacy-and-integrity

117 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 5. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

118 UNICEF (2024). Neurotechnology and Children. p. 15. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

From a technical perspective, neurotechnologies' use has to deal with complex wiring, battery life,[119] and data availability. Especially, in the case of children with neurodevelopmental disorders, the technology also needs to work with their little attention.[120] Additionally, some scholars argue that neuroimaging datasets are small-scale due to data availability, to which anonymized data can be a solution. Nevertheless, scholars argue that neural networks can extract identifiable features from these anonymized images such as age and sex that can further identify a person using features such as hospital location and illness.[121] Furthermore, like any other devices, brain-computer interfaces are susceptible to cybersecurity risks that could compromise an individual's intentions when using the technology. This is critical when treating a locked-in syndrome where an individual cannot express their wishes.[122] Similar worries can arise when there is remote management of neurotechnologies or when the data is stored externally.[123] Cybersecurity and safety are also significant for non-medical devices as they face weaker regulations as compared to medical devices.[124] Moreover, the development of neurotechnologies must seek solutions to minimize contamination or noise during the processing of neurodata. This can easily happen because often, neurotechnologies also record muscle and simple movement at the moment of the measurement, which can alter the neurodata.[125]

Accuracy is another vital consideration for neurotechnologies, yet questions remain about its feasibility. Different levels of invasiveness in neurotechnologies can lead to varying amounts and quality of information. Additionally, due to the neuroplasticity/brain plasticity, which means that the "neurodata is in flux from any moment to another," the question arises: for how long does neurodata remain accurate?[126] This plasticity is even more evident in children, whose brains are still developing, and this development does not occur uniformly across all age groups.[127] According to the ICO, a potential solution is to avoid making decisions based on singular instances of neurodata and instead focus on larger data sets. However, this puts the data minimization principle at further risk.[128] Moreover,

119 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 10. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

120 UNICEF (2024). Neurotechnology and Children. p. 14. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

121 Dinsdale NK, Bluemke E, Sundaresan V, Jenkinson M, Smith SM, Namburete AIL (2022, December 7) Challenges for Machine Learning in Clinical Translation of Big Data Imaging Studies. Neuron. https://doi.org/10.1016/j.neuron.2022.09.012

122 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 13. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

123 Bitbrain team (2018, November 21). Avoiding brain hacking - Challenges of Cybersecurity and Privacy in Brain Computer Interfaces. Bitbrain. https://www.bitbrain.com/blog/cybersecurity-brain-computer-interface

124 Regulatory Horizon Council (2022). Neurotechnology Regulation. pp. 41, 43. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

125 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience-Societal, Legal and Ethical Challenges. p. 167. https://www.europarl.europa.eu/RegData/etudes/STUD/2024/757807/EPRS_STU(2024)757807_EN.pdf

126 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 21. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

127 UNICEF (2024). Neurotechnology and Children. pp. 8, 14. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

128 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 21. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

there is some concern regarding the longevity of neurotechnologies or the need for recalibration due to cell death or atrophy.[129]

Legally, neurotechnologies challenge traditional notions of consent, intermediary responsibility, and data privacy principles. The Australian Human Rights Commission asks: "[c]an genuine informed consent truly be obtained?"[130] This query takes into account patients or individuals who cannot provide free consent. This is also the case in workplaces, where employees may struggle to give consent regarding the consequences of neurotechnological applications on hiring, promotions, and disciplinary measures.[131] [132] Moreover, the Australian Human Rights Commission highlights the challenge of drawing the lines between sole responsibility and third-party responsibility of the neurotechnology when dealing with offenders.[133] Compliance with data privacy principles poses another challenge given that many neurotechnology providers are based in the United States. A study by the Neurorights Foundation corroborates this concern; they found out that 60 per cent of the companies they studied do not provide information about how the data is processed or the rights the individuals might have.[134] [135]

Ethical considerations also loom large in the discussion of neurotechnologies. The International Bioethics Committee of UNESCO expressed concern regarding the potential impact on public understanding and acceptance of neurodiversity. For example, cochlear implants have been already questioned by the deaf community because they signal a lack of acceptance of deafness.[136] Similarly, UNICEF raises alarms about the implications of developing neurotechnologies for children, highlighting the risks of conducting experiments on vulnerable populations and the potential reinforcement of power asymmetries.[137]

Additionally, the perception of commercial or non-medical neurotechnologies poses challenges. The Regulatory Horizon Council has reported a considerable degree of hype in the neurotechnology sector that has been reported by neuroethicists, neuroscientists, and government organizations who talk about the effectiveness of non-medical

129 Welle, C. G., Gao, Y. R., Ye, M., Lozzi, A., Boretsky, A., Abliz, E., & Hammer, D. X. (2020). Longitudinal Neural and Vascular Structural Dynamics Produced by Chronic Microelectrode Implantation. Biomaterials, Volume 238. https://doi.org/10.1016/j.biomaterials.2020.119831

130 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 20. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

131 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 19. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

132 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 21. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

133 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 26. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

134 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 70. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

135 Roda, C. (2024, July 3). Mental privacy and integrity. https://iapp.org/news/a/mental-privacy-and-integrity

136 International Bioethics Committee (2021). Ethical issues of neurotechnology. UNESCO. p. 20. https://doi.org/10.54678/QNKB6229

137 UNICEF (2024). Neurotechnology and Children. p. 15. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

neurotechnology.[138] The reputation of neuroscience is creating a "neuro-enchantment" about it that affects critical assessment of it.[139] According to the Panel for the Future of Science and Technology, there is limited understanding of possible negative side effects. Research on neurotechnologies often seems to cover a short period of weeks, and this problem has already been pointed out by scientists.[140] This issue may stem from the fact that the analytical processes applied to medical devices differ from those used for non-medical devices, leading to insufficient verification of commercial neurotechnologies before they reach the market.[141] On top of that, the ICO warns that in a non-medical context, neurodata could not be categorized as special or sensitive data which legally reduces the barriers.[142] The consequences of this hype and the notion of "neuro-enhancement" that affects a clear and fair assessment suggest that neurotechnologies may be perceived as faultless. In consequence, in work settings, neurotechnologies are seen as the solution against deceitful employees or to correct employees' natural mistakes."[143]

Neurotechnologies also create a socio-economic challenge. The Australian Human Rights Commission noted that the maintenance of neurotechnology devices requires ongoing support and updates. Otherwise, individuals may find themselves relying on redundant or obsolete technology. This could happen if the individual does not have adequate resources to keep up with the updates and pay the maintenance fees or if the companies go bankrupt.[144] Another power imbalance problem could arise between people who can get the devices to improve their lives and those who develop and maintain the devices.[145] Notably, there are concerns regarding the potential use of brain-computer interfaces for cognitive augmentation, as highlighted by IEEE Brain[146] and by religious groups in the United States who believe human enhancement technologies would be meddling with nature.[147]

138 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 44. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

139 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. pp. 10, 68. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

140 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. pp. 7, 8. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

141 Regulatory Horizon Council (2022). Neurotechnology Regulation. pp. 40, 45. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

142 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 19. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

143 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 20. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

144 A situation like this happened when Second Sight discontinued its Argus II bionic eye due to financial problems, leaving its customers with no further support or communication. Wakefield, J. (2022, February 17). Bionic eyes: Obsolete Tech Leaves Patients in the Dark. BBC. https://www.bbc.com/news/technology-60416058

145 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. pp. 20, 21. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

146 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 17. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

147 Fahmy, D. (2022, May 4). Highly Religious Americans more Skeptical of Human Enhancements such as Brain Implants, Gene Editing. Pew Research Center. https://www.pewresearch.org/short-reads/2022/05/04/highly-religious-americans-more-skeptical-of-human-enhancements-such-as-brain-implants-gene-editing/

Finally, Canada has obligations and considerations that must be taken into account for Indigenous people and communities and the use of neurotechnology. Indigenous views about cognition can vary from Western approaches. Indigenous views can "emphasize experience and locate the centre of thought and cognition within the interconnectedness of the body with the environment."[148] Similarly, in the case of data governance, First Nations' principles of ownership, control, access, and possession of data may affect how Indigenous-related information is collected and managed. Special attention is given to data that includes First Nation people's health information, languages, patterns, songs, and more which should be governed by First Nations laws no matter where in Canada the data is.[149] These positions are reflected in Indigenous people's interest in collective privacy.[150] Nevertheless, First Nations and Inuit people experience health issues such as high levels of mental illness that are a direct consequence of assimilative policies and laws and the history of colonization.[151] Additionally, First Nations communities have faced widespread stigma related to perceptions of their health.[152] As with other vulnerable populations, equitable access to health services is a concern.[153] On top of that, according to a Government of Canada's report, government institutions tend to hold more personal information about First Nations persons than other Canadians, with much of it being classified as sensitive information.[154] The result is that any neurotechnologies that are developed, or deployed, must respect Indigenous sovereignty, laws, and governance structures including being sensitive to different data governance obligations.

4. Neurotechnologies being adopted

4.1 Health

According to the Regulatory Horizon Council, a medical neurotechnology device is defined as "product whose purpose is to diagnose, prevent, monitor, treat, or alleviate neurological

148 Tesluk, J., Illes, J., & Matthews, R. (2017). First Nations and Environmental Neuroethics: Perspectives on Brain Health from a World of Change. In Oxford University Press eBooks. p. 465. https://doi.org/10.1093/oso/9780198786832.003.0023

149 First Nations Information Governance Centre. (2024). A First Nations Guide to the Privacy Act. p. 4. https://fnigc.ca/wp-content/uploads/2024/08/FNIGC_FN_Guide_Privacy_Act_EN-1.pdf

150 Government of Canada, Department of Justice, Electronic Communications. (2022, March 2). Privacy Act Modernization: Engagement with Indigenous Partners – What We Have Learned (so far) and Next Steps. https://www.justice.gc.ca/eng/csj-sjc/pa-lprp/wwh3-cqnae3/part1-partie1.html

151 Tesluk, J., Illes, J., & Matthews, R. (2017). First Nations and Environmental Neuroethics: Perspectives on Brain Health from a World of Change. In Oxford University Press eBooks. p. 461. https://doi.org/10.1093/oso/9780198786832.003.0023

152 Tesluk, J., Illes, J., & Matthews, R. (2017). First Nations and Environmental Neuroethics: Perspectives on Brain Health from a World of Change. In Oxford University Press eBooks. p. 463. https://doi.org/10.1093/oso/9780198786832.003.0023

153 Illes, J., Lipsman, N., McDonald, P. J., Hrincu, V., Chandler, J., Fasano, A., Giacobbe, P., Hamani, C., Ibrahim, G. M., Kiss, Z., Meng, Y., Sankar, T., & Weise, L. (2021). From Vision to Action: Canadian Leadership in Ethics and Neurotechnology. International Review of Neurobiology, 159, p. 251. https://doi.org/10.1016/bs.irn.2021.06.012

154 Government of Canada, Department of Justice, Electronic Communications. (2022, March 2). Privacy Act Modernization: Engagement with Indigenous Partners – What We Have Learned (so far) and Next Steps. https://www.justice.gc.ca/eng/csj-sjc/pa-lprp/wwh3-cqnae3/part1-partie1.html

disease or injury."[155] Significant research and development efforts have led to a wide array of neurotechnologies being utilized for health purposes.

For instance, imaging technologies derived from EEG, like evoked potentials, event-related potentials, and functional magnetic resonance imaging, have been used in the medical sector to detect illness and monitor neural systems.[156] Additionally, neuroprostheses have also been used to recreate sensations. Notable examples are cochlear and auditory brainstem implants. These technologies bypass damaged parts of the cochlea and stimulate the auditory nerve to help the person hear.[157] Some authors, including UNICEF, argue that cochlear implants should be considered a brain-computer interface.[158]

Neurostimulation and neuromodulation technologies also play a vital role in medical applications. Deep brain stimulation, recognized vastly in literature, has been used since 1997 to reduce symptoms and treat Parkinson's disease by delivering electric impulses to the basal ganglia.[159] [160] [161] [162] [163] Deep brain stimulation is also applied for treating essential tremors, dystonia,[164] and epilepsy.[165] In the future, it could be used to treat depression, obsessive-compulsive disorders,[166] and cerebrovascular diseases.[167] Similarly, neuromodulation technologies such as those wearables developed by Neurovalens,[168] may assist in treating addiction, obesity, insomnia, anxiety, and post-traumatic stress disorder.[169]

Neural interfaces represent another critical technology in the medical field. Brain-machine interfaces help people to restore sensory, nervous, and motor functions with the effect of

155 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 22. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

156 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 3. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

157 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 15. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

158 UNICEF (2024). Neurotechnology and Children. p. 9. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

159 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 18. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

160 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 12. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

161 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 4. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

162 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 8. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

163 International Bioethics Committee (2021). Ethical issues of Neurotechnology. UNESCO. p. 19. https://doi.org/10.54678/QNKB6229

164 UNICEF (2024). Neurotechnology and Children. p. 13. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

165 International Bioethics Committee (2021). Ethical issues of Neurotechnology. UNESCO. p. 19. https://doi.org/10.54678/QNKB6229

166 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 4. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

167 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 13. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

168 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 14. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

169 Information Commissioner's Office (2023). ICO tech futures: Neurotechnology. p. 13. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

allowing patients to control robotic arms, exoskeletons, and their own paralyzed parts of the body.[170] [171] Furthermore, interfaces used to get a diagnosis are helpful in cases where the person experiences disorders of consciousness. This technology combined with modulation capabilities can bypass the eye and optic nerve to introduce images to the brain to help people see. Brain-computer interfaces are also emerging to enhance cognitive abilities and physical health, often referred to as wellness devices, though their efficacy is still under evaluation.[172]

Additionally, when paired with neurofeedback capabilities, these technologies can be applied to modulate and treat anxiety, depression, chronic pain, and sleep disorders.[173] In the non-invasive methods, the person learns to modulate their brain by feeding it back with visual, auditory, and tactile means.[174]

4.2 Employment

Employment is another area where neurotechnologies hold significant promise to surveil workers, understand and enhance their performance, and make hiring and promotion decisions.[175] Although this is the promise, Muhl and Andorno have highlighted potential ethical issues such as an increase of power imbalance, a threat to privacy, and a risk of discrimination.[176]

The ICO predicted in a report published in 2023 that neurotechnology would be readily adopted within four to five years.[177] Neuroimaging technology has been used to measure and monitor levels of attention, mind wandering, and effort withdrawal[178] of the worker for their health and safety, particularly in risky environments.[179] This can help identify

170 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 16. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

171 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 12. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

172 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 12. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

173 UNICEF (2024). Neurotechnology and Children. p. 8. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

174 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 6. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

175 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 7. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

176 Muhl, E., & Andorno, R. (2023). Neurosurveillance in the Workplace: Do Employers Have the Right to Monitor Employees' Minds? Frontiers in Human Dynamics, 5, 1245619. https://doi.org/10.3389/fhumd.2023.1245619

177 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 35. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

178 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 35. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper. Effort withdrawal means reducing the effort put in activities.

179 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 14. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

neuropathologies.[180] Notable examples include the SmartCap, which assesses engagement, and AttentivU glasses, which track eye movements.[181] The international company Wenco that has its headquarters in Canada, produces a SmartCap for the mining sector, a device that helps the user monitor their alertness during working hours. While there is no public information about its use in Canada, more than 5,000 companies worldwide use this technology in various industries such as mining, construction, trucking, and aviation.[182]

What is more, neuromodulation technologies could be used to improve employees' performance. For instance, transcranial direct current stimulation can be used to combat fatigue making it particularly relevant for employees in high-stress occupations such as firefighters, nurses, and emergency medical personnel.[183] [184] This application has been studied by researchers at Texas A&M University and is as of writing being developed by Caputron.[185] [186] Additionally, brain interfaces are being used by Chinese factories, state-owned companies, and in various transport contexts, to collect employees' moods.[187]

4.3 Law enforcement

Neurotechnologies present new possibilities for law enforcement.[188] While it is still in its early days and very few have written or reported about it, there are already developments in neuroimaging and neurostimulation technologies. The most advanced use has been as a lie detection tool using imaging neurotechnologies. EEG techniques measure the brain waves to assess whether a person is lying.[189] For instance, in India, brain electrical oscillation signature profiling is used to interrogate alleged criminals, even if there is no proof of its accuracy.[190] Concerns about this have been raised when it is used to predict and prevent behaviors. UNICEF has raised alarms about using such technologies to assess adolescents'

180 Muhl, E., & Andorno, R. (2023). Neurosurveillance in the Workplace: Do Employers Have the Right to Monitor Employees' Minds? Frontiers in Human Dynamics, 5, 1245619. https://doi.org/10.3389/fhumd.2023.1245619

181 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. pp. 17, 18. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

182 Farahany, N. (2023a). Neurotech at Work. Welcome to the World of Brain Monitoring for Employees. Harvard Business Review. https://hbr.org/2023/03/neurotech-at-work

183 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 39. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

184 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 35. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

185 Regulatory Horizon Council (2022). Neurotechnology Regulation. p. 39. https://assets.publishing.service.gov.uk/media/63e9e8f88fa8f5050ee37d10/rhc-neurotechnology-regulation.pdf

186 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 18. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

187 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Inerfaces. p. 18. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

188 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age ofNeuroscience and Neurotechnology. BioMed Central. p. 2. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

189 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. p. 25. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

190 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 11. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

propensity for risky behaviors, highlighting the potential stigmatization that it could create.[191] Another potential use of neurotechnologies like EEG could be, according to some scholars, for forensic assessment once neurotechnologies can reliably show individual psychological conditions.[192]

Moreover, transcranial direct current stimulation and transcranial magnetic stimulation have possible applications in law enforcement. This is because they are non-invasive and they have short-term effects. These technologies stimulate parts of the brain and measure if there is a slow response to determine untruthfulness in a statement. However, this raises ethical questions about the potential for enhanced interrogation methods and the risk of non-consensual pleas of guilt. Additionally, there could be a possibility of applying neurotechnologies as a mental health treatment ordered by a judge to reduce the risk of reoffending, and even as a tool to retrieve long-term memories.[193]

5. Legal issues

Various scholars and institutions have raised concerns about the negative consequences and challenges that neurotechnology poses. For the European Data Protection Supervisor and Agencia Española de Protección de Datos, neurotechnologies put human rights at risk broadly; more than just the right to privacy is jeopardized.[194] Illes further notes that while neuroethics debates in the 2000s focused primarily on free will, the discourse has now shifted globally toward human rights. In that sense, neuroethics scholars are writing about international legal systems and guidance.[195] In this context, neurotechnologies are examined first against human dignity as this foundational value relates directly to the essence of being human.[196] There is a strong emphasis on ensuring that neurotechnologies do not replicate biases and are transparent, traceable, explainable, grounded in solid evidence, and supported by clear frameworks for responsibility and accountability.[197] The following sections develop the impact on different human rights. Later, this section discusses the legal responses proposed by different scholars and organizations.

191 UNICEF (2024). Neurotechnology and Children. p. 22. https://www.unicef.org/innocenti/media/8956/file/UNICEF-Innocenti-Neurotechnology-and-Children-2024.pdf

192 Kempes M (2023). Added Value of Neurotechnology for Forensic Psychiatric and Psychological Assessment. Handb Clin Neurol. https://doi.org/10.1016/B978-0-12-821375-9.00015-3

193 Australian Human Rights Commission (2024). Protecting Cognition: Background Paper on Human Rights and Neurotechnology. pp. 25, 26. https://humanrights.gov.au/our-work/technology-and-human-rights/publications/protecting-cognition-background-paper

194 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 15. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

195 Illes, J. (2023). Reflecting on the past and future of neuroethics: The Brain on a Pedestal. AJOB Neuroscience, 14(3), 223–226. p. 3. https://doi.org/10.1080/21507740.2023.2188282

196 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 17. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

197 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 12. https://unesdoc.unesco.org/ark:/48223/pf0000391074

5.1 Privacy

The right to privacy, entrenched in Article 17 of the International Covenant on Civil and Political Rights, serves as an essential safeguard for dignity, identity, and autonomy.[198] For some scholars, privacy is also an ability — an individual's capacity to control the flow of personal data and protect private information.[199] [200] As a human right, interference or restrictions are only allowed in the interests of society.[201] For instance, the European Data Protection Supervisor and Agencia Española de Protección de Datos consider that the capture of "brain fingerprints" can only be done for health purposes.[202]

The use of neurotechnologies poses significant challenges to the right to privacy. On one hand, this technology enables individuals to access and monitor their own brain activity, allowing for self-monitoring, brain-controlled computing, and neuroenhancements.[203] However, the regulatory frameworks governing this control vary widely across jurisdictions.[204] On the other hand, the data collected through neurotechnologies is extensive, diverse,[205] and inherently involuntary and intrinsic.[206] It encompasses highly sensitive information such as personality traits, sexual orientation, cognitive performance, mental states,[207] and could be used to make inferences about the person. Unlike traditional data that was recorded or shared, this creates a different paradigm as this data is generated

198 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 23. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

199 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 29. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

200 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologiesand AI. Nature. p. 161. https://www.nature.com/articles/551159a

201 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 23. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

202 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 17. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

203 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 12. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

204 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee.. United Nations Digital Library System. Par. 25. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

205 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 12. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

206 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 18. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

207 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 24. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

and stored in the mind.[208] Therefore, neurotechnology, especially neuroimaging, creates the possibility of extracting information without the individual being aware.[209] [210]

Neurotechnology also affects data privacy principles, particularly transparency, accuracy, and minimization. For instance, its use for closed-loop processing is complex enough to provide full transparency on what is happening.[211] Additionally, neuroplasticity, especially significant in individuals aged 5 to 30,[212] affects the accuracy of neurodata over time, often necessitating the collection of additional information, which raises the risk of excessive data retention.[213] These issues also challenge the proportionality principle, as the extensive baseline collection of neurodata makes it difficult to ensure that the use of a certain neurotechnology is adequate or necessary, given the inherent accuracy limitations.[214]

Furthermore, according to the ICO neurotechnologies also impact the exercise of data privacy rights. While individuals have the right to access personal data used for identification, doing so with raw neurodata can be challenging. The right to correct personal data is also complicated, as neurodata may be collected without individuals' awareness, making this right difficult to apply. Furthermore, individuals also have the right to transfer their data to other providers, but if multiple commercial standards emerge this can make it difficult. Finally, individuals have the right to delete their information, but exercising this right can impact algorithmic processing.[215]

5.1.2 How to classify neurodata?

There is an ongoing debate about whether neurodata should be classified as personal data. Neurodata can be considered personal if it identifies or enables the identification of an individual. For example, in the European Union, Article 4 (1) of the GDPR and the Court of Justice of the European Union cases *Breyer and Nowak* states specify that brain and mental data qualify as personal data only when it is possible to single out the individual involved.[216] For some authors, this is not questionable as "a data signal cannot be divorced from the

208 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 12, 13. from https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

209 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 46. https://doi.org/10.54678/QNKB6229

210 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 12. https://unesdoc.unesco.org/ark:/48223/pf0000391074

211 Information Commissioner's Office (2023). ICO tech futures: Neurotechnology. p. 21. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

212 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 17. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

213 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 21. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

214 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. pp. 16, 18. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

215 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 22. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

216 Magee, P., Ienca, M., & Farahany, N. (2024). Beyond Neural Data: Cognitive Bbiometrics and Mental Privacy. Neuron, 112(18), p. 3021. https://doi.org/10.1016/j.neuron.2024.09.004

identity that provided that signal" making the electroencephalography signal an identifier.[217] [218] [219] [220] However, others argue that such identification will be uncommon, as neurodata is more likely to be used for classification rather than direct identification, given its cost and complexity compared to other biometric options.[221] In consequence, there will be neurodata that won't qualify as personal data and specific protections should be in place.[222] Additionally, industry standards also remain unclear. According to a study conducted by Neurorights Foundation, 43 per cent of the companies studied mention neurodata in their policy documents, and another 30 per cent do not mention it.[223]

There is a broader consensus on categorizing neurodata as a special category of data. For some, its categorization depends on the purpose of its processing;[224] for others, it depends if neurodata can be interpreted as biometric data.[225] Scholars generally agree that neurodata should be treated as sensitive due to the depth of personal information it can reveal and its potential misuse.[226] [227] [228] Reflecting these concerns, some authors in Europe are asking to include neurodata in Article 9 of the GDPR.[229] [230]

5.1.3 New data categories: mental data and cognitive biometric data

Some scholars are proposing two new categories of data: mental data and cognitive biometric data. Mental data is "any data that can be organized and processed to infer the

217 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 14. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

218 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 32, 48. https://doi.org/10.54678/QNKB6229

219 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 4. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

220 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 18. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

221 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 17. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

222 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 7, 26. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

223 Genser, J., Damianos, S., & Yuste, R. (2024). Safeguarding Brain Data: Assessing the Privacy Practices of Consumer Neurotechnology Companies. p. 3. https://www.perseus-strategies.com/wp-content/uploads/2024/04/FINAL_Consumer_Neurotechnology_Report_Neurorights_Foundation_April-1.pdf

224 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 8. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

225 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 30. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

226 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 47. https://doi.org/10.54678/QNKB6229

227 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 16. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

228 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p.16. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

229 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 52. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

230 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 26. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

mental states of a person, including their cognitive, affective, and conative states."[231] If this data can be linked to an individual, it is considered personal data. Cognitive biometric data, in contrast, is defined as any data collected through biometric and biosensor data that can "be processed and used to infer mental states"[232] with the defining difference being its biometric and biosensor origins. Scholars like Magee, Farahany, and Ienca suggest that cognitive biometric data provides a clearer legal framework. This proposed category addresses the fact that various consumer devices, beyond neurotechnologies, also collect and transmit mental state data.[233] Also this term is proposed to include data that will not be used for identification, data that does not come directly from the nervous system, and data about consumer preferences that are not considered sensitive according to current legislation. It also includes non-affective mental states that are outside the scope of the EU *AI Act*, which primarily focuses on protecting emotional data.[234]

5.1.4 A consent problem

The processing of neurodata requires a clear legal basis, with consent typically being the foundation for such processing. The use of neurotechnology creates doubts about the validity of informed consent, as these technologies can alter, mimic, enhance, or interfere in different degrees with the free will and a capable mind to provide consent. For instance, deep brain stimulation has raised concerns as it can impact identity, autonomy, and authenticity of an individual.[235] Additionally, the complexity of neurotechnology and the use of algorithms that are difficult to explain hinder individuals' ability to fully understand what they are consenting to.[236] [237] Scholars offer varying solutions to address this challenge. For instance, for Ienca and Bertoni, "informed consent" should be continuously updated,[238] while Yuste, proposes treating neurodata similarly to organs and tissues, with a default opt-out option.[239] Similarly, Neurorights Foundation recommends explicit consent to be provided in every case.[240] The ICO, however, argues that consent is not inherently better than other bases for processing. According to ICO, when consent is not appropriate, it is possible to consider legitimate interest or contractual obligation as basis for data processing. ICO warns, however, that

231 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 6, 7. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

232 Magee, P., Ienca, M., & Farahany, N. (2024). Beyond Neural Data: Cognitive Biometrics and Mental Privacy. Neuron, 112(18), p. 3022. https://doi.org/10.1016/j.neuron.2024.09.004

233 Magee, P., Ienca, M., & Farahany, N. (2024). Beyond Neural Data: Cognitive Biometrics and Mental Privacy. Neuron, 112(18), pp. 3017, 3022. https://doi.org/10.1016/j.neuron.2024.09.004

234 Magee, P., Ienca, M., & Farahany, N. (2024). Beyond Neural Data: Cognitive Biometrics and Mental Privacy. Neuron, 112(18), pp. 3020-3021. https://doi.org/10.1016/j.neuron.2024.09.004

235 Zuk P, Sanchez CE, Kostick-Quenet K, Muñoz KA, Kalwani L, Lavingia R, Torgerson L, Sierra-Mercado D, Robinson JO, Pereira S, Outram S, Koenig BA, McGuire AL, Lázaro-Muñoz G (2023). Researcher Views on Changes in Personality, Mood, and Behavior in Next-Generation Deep Brain Stimulation. AJOB Neurosci. Jul-Sep;14(3): 287-299. https://doi.org/10.1080/21507740.2022.2048724

236 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 19. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

237 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 31, 45. https://doi.org/10.54678/QNKB6229

238 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 10. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

239 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologiesand AI. Nature. p. 161. https://www.nature.com/articles/551159a

240 Information Commissioner's Office (2023). ICO Tech futures: Neurotechnology. p. 17. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

using legitimate interest would likely not pass a three-part test due to the high risks, intimate information processes, and the difficulty to set clear expectations for people.[241]

5.2 Freedom of thought

The right to freedom of thought is recognized in different international legal texts such as Articles 18 of the International Covenant on Civil and Political Rights, 13 of the American Convention on Human Rights, 9 of the European Convention on Human Rights, 8 of the African Charter on Human and Peoples' Rights. Particularly Article 7 of the International Covenant on Civil and Political Rights could be interpreted as a protection against brain-reading and brain-writing neurocorrectives as they constitute a degrading treatment.[242] Additionally, the EU *AI Act* in its article 5.2.2 classifies the use of AI to manipulate persons through subliminal techniques as unacceptable.[243]

The right to freedom of thought is considered a cornerstone of freedom of opinion and expression that nourishes democracy.[244] This right encompasses two dimensions: the *forum internum* and the *forum externum*. The *forum internum* constitutes "the inner, psychological realm of the person, where thoughts and convictions are formed"[245] and is where the individual creates their positions about life and other convictions. The *forum externum* pertains to the external manifestation of these thoughts.[246] However, this right has not been applied extensively and when invoked in courts it has been to protect the means ordering the thought, not the thoughts themselves.[247] The UN Human Rights Council Advisory Committee has called for a clearer definition of this right, given its limited application. This is significant because neurotechnology creates potential risks that are related to the *forum interum* such as mind reading, a criminalization of mere thought, and the possibility of interfering and manipulating individuals.[248]

241 Information Commissioner's Office (2023). ICO Tech futures: Neurotechnology. p. 20. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

242 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. par. 34 https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

243 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. pp. 33-34. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

244 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 36. https://doi.org/10.54678/QNKB6229

245 Human Rights Council Advisory Committee (2024, August 8).Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par.18 https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

246 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 50. https://doi.org/10.54678/QNKB6229

247 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 51. https://doi.org/10.54678/QNKB6229

248 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par 20-22. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

5.3 Integrity

The right to physical and mental integrity has been enriched in different legal instruments such as Article 1 of the Universal Declaration of Human Rights, article 17 of the Convention on the Rights of Persons with Disabilities, and regional charters such as Article 3 of the European Charter of Fundamental Rights. In theory, these instruments protect mental activities from manipulation and alteration without informed consent.[249]

Neurotechnologies pose specific risks to the right to freedom of thought by intervening in brain activities, which complicates the process of obtaining free and informed consent.[250] Additionally, it can have adverse effects including apathy, compulsive behavior, and hallucinations creating alteration in mental states, endangering the individual of autonomous control, and impacting their identity.[251] [252] Furthermore, the security vulnerabilities associated with neurotechnologies are significant. Ienca and Andorno warn about malicious actors that can add noise or override signals to manipulate a person or selectively erase memories. This is particularly important for people in vulnerable situations where others can exercise coercion or the individual is legally incompetent, such as children.[253] [254]

5.4 Identity

The right to have an identity or personality is safeguarded by Article 22 of the Universal Declaration of Human Rights as everyone is entitled to develop their personality freely. Neurotechnology can affect the development of an individual's identity with the faster translation between a brain and a machine, and the possibility to wire different brains.[255] This coupled with its adverse effects from violations of the freedom of thought and integrity can disrupt the identity and agency of a person. Yuste argues that, in some cases, individuals may behave in ways that no longer align with their true identity, leading to confusion about who they truly are.[256]

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249 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 46. https://doi.org/10.54678/QNKB6229

250 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 46. https://doi.org/10.54678/QNKB6229

251 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Right: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 27. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

252 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age ofNeuroscience and Neurotechnology. BioMed Central. pp. 19, 20. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

253 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 29. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

254 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age ofNeuroscience and Neurotechnology. BioMed Central. pp. 17, 19, 21. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

255 Yoo, S., Choi, K., Nam, S., Yoon, E., Sohn, J., Oh, B., Shim, J., & Choi, M. (2023). Development of Korea Neuroethics Guidelines. Journal of Korean Medical Science, 38(25). p. 6. https://doi.org/10.3346/jkms.2023.38.e193

256 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologies and AI. Nature. p. 162. https://www.nature.com/articles/551159a

5.5 Discrimination

The right to be free from discrimination is firmly established in various legal frameworks. For instance, Article 26 of the International Covenant on Civil and Political Rights states that all persons are equal and protects individuals against discrimination based on race, color, sex, language, religion, political or other opinions, national or social origin, property, birth or other status. Nevertheless, neurotechnologies pose potential risks to this right through their design, use, and accessibility.

The European Data Protection Supervisor and the Agencia Española de Protección de Datos have highlighted the risk of discrimination arising from insufficient testing of these technologies, which may lead to biases or incomplete datasets.[257] Neurotechnologies could be used to create mental profiles that facilitate discriminatory practices, such as in hiring processes or insurance assessments.[258] Moreover, unequal access to these technologies could exacerbate existing health disparities, with some communities facing structural barriers to obtaining them.[259]

5.6 Right to a fair trial

The right to a fair trial, as outlined in Article 10 of the Universal Declaration of Human Rights, guarantees everyone a fair and public hearing. Neurotechnology, due to its capacity to obtain intimate data that in the past was beyond reach, becomes relevant in legal contexts, particularly within the emerging field of neurolaw. For example, neurotechnology as a lie detection technology can be used to assess the reliability of witnesses. Nonetheless, their use raises significant concerns, particularly regarding violations of due process.[260] These include the risk of involuntary self-incrimination when neurodata is disclosed without consent and subsequently used as evidence.[261]

5.7 Legal responses

There are different legislative proposals to better protect the individual. Some authors argue that existing frameworks are insufficient and inadequate,[262] while others believe that

257 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 19. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

258 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 25. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

259 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 32, 33. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

260 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 36. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

261 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. pp. 5, 6, 17. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

262 Greenberg, J., Ringrose, K., Berger, S., VanDodick, J., Rossi, F., & New, J. (2021). Privacy and the Connected Mind. Understanding the Data Flows and Privacy Risks of Brain-Computer Interfaces. p. 31. https://fpf.org/wp-content/uploads/2021/11/FPF-BCI-Report-Final.pdf

current consumer protection, competition, and product safety laws already address these concerns.[263] In sum, there are three major groups. A first group that introduces new rights, an intermediary group that proposes amendments to current legislation, and a third group that states that there is no need to change or amend current legislation.

5.7.1 New rights

a) Cognitive liberty

The first works that postulate the idea of cognitive freedom come from Richard Glen Boire and Wrye Sententia. There is a particular work from 2003 titled *Mind Matters* where they made an explicit call for the first time about the effect of drugs on thinking and how the government can force people to take certain medications in specific situations. The authors note: "It is time to develop a jurisprudence on the mind; one that takes into account the latest knowledge about the brain, the advanced powers of psychopharmacology, and that places them within our country's tradition of embracing individual freedom, self-determination, and cognitive freedom is the human right that most needs immediate elaboration and defense."[264]

Ten years later, in 2023, Bublitz published a chapter where he proposes the legal conceptualization of cognitive liberty or mental self determination. According to Bublitz, this right has three dimensions: a liberty to change one's mind, a protection against intervention to preserve mental integrity, and an obligation for states to promote cognitive liberty.[265]

Based on Richard Glen Boire and Wrye Sententia work, later in 2017, a paper written by Ienca and Androno titled, "Towards new human rights in the era of neuroscience and neurotechnology," proposed for the first time a "neuro-oriented human rights framework" that included cognitive liberty among other rights. Its inclusion was based on the reasoning that this right resembles freedom of thought, as it is essential to other liberties.[266]

Similarly, Farahany has contributed significantly to the discourse on cognitive liberty, framing it as an update to traditional liberty in the digital era by providing "self-determination over our brains and mental and experiences and protect our mental privacy and freedom of thought."[267] Farahany also argues that the idea of cognitive liberty is already implicit in existing human rights such as privacy, freedom of opinion and expression, freedom of thought, right to education, health, and the right to participate in cultural life.[268] Therefore, cognitive liberty provides a framework that integrates freedom of thought, self -self-determination, and privacy

263 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 66. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

264 Dubois, S. O., Boire, R. G., & Lypps, H. (2003). Journal of Cognitive Liberties. Center for Cognitive Liberty & Ethics (Ccle). pp. 9,10. https://www.cognitiveliberty.org/ccle1/10jcl/jcl_vol4num1.pdf

265 Bublitz, J.C. (2013). My Mind Is Mine!? Cognitive Liberty as a Legal Concept. p. 19. https://link.springer.com/chapter/10.1007/978-94-007-6253-4_19

266 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 10. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

267 Farahany, N. (2023c, June 26). 'Cognitive Liberty' is the Human Right we Need to Talk About. TIME. https://time.com/6289229/cognitive-liberty-human-right/

268 Farahany, N. (2023d). Submission to the Advisory Committee on the Questionnaire on "Neurotechnology and Human Rights." https://www.ohchr.org/sites/default/files/documents/hrbodies/hrcouncil/advisorycommittee/neurotechnology/04-academia/ac-submission-academia-farahany.pdf

that can be applied across different technologies including neurotechnology, social media platforms, generative AI, immersive technologies, and more.[269]

According to UNESCO, cognitive liberty can be understood in two ways. As Ienca and Andorno suggest, it can be viewed as a negative right — a prerequisite for all neuro-related rights. Alternatively, it can be framed positively, advocating for a right to cognitive enhancement and ensuring broad access to neurotechnological advancements.[270] Something similar has already been proposed in the Convention on the Rights of Persons with Disabilities. Article 4.1. (g) calls for states/parties to promote the full realization of all human rights and freedoms of persons with disabilities by promoting the development of assistive technologies.

b) Neurorights

There is no consensus on what constitutes neurorights. Diverse authors have designed a list of neurorights that should be recognized in legislation as explained below.[271]

In their 2017 neuro-oriented human rights framework Ienca and Androno called for: cognitive freedom, mental privacy, mental integrity, and the right to psychological continuity.[272] Their approach called for further development of existing rights, including on previous work concerning cognitive freedom as well as developing a new right. The new right that they proposed was the right to psychological continuity, which is meant "to preserve personal identity and the coherence of the individual's behavior from unconsented modification by third parties." In other words, this new right will protect the underlying neural functioning.[273]

Also in 2017, Yuste and other scholars published an article called "Four Ethical Priorities for Neurotechnologies and AI."[274] The four concerns they detail are privacy and consent, agency and identity, augmentation, and bias, and they explicitly point out that agency and identity should be protected as a basic right. Based on this work, Yuste and the Neurorights Foundation later set the list of five neurorights: mental privacy, personal identity, free will, fair access to mental augmentation, and protection from bias[275] and called for an absolute right to request deletion to protect privacy.[276]

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269 Farahany, N. (2023d). Submission to the Advisory Committee on the Questionnaire on "Neurotechnology and Human Rights." https://www.ohchr.org/sites/default/files/documents/hrbodies/hrcouncil/advisorycommittee/neurotechnology/04-academia/ac-submission-academia-farahany.pdf

270 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 53. https://doi.org/10.54678/QNKB6229

271 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 7. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

272 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

273 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 21. from https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

274 Yuste, R., Goering, S., Arcas, B. et al. (2017). Four Ethical Priorities for Neurotechnologies and AI. Nature. https://www.nature.com/articles/551159a

275 The Neurorights Foundation (n.d.-b). Our Story. https://neurorightsfoundation.org/mission

276 Information Commissioner's Office (2023). ICO Tech Futures: Neurotechnology. p. 34. https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf

Various actors have also offered their interpretations of neurorights. For instance, the European Data Protection Supervisor and Agencia Española de Protección de Datos list neurorights: cognitive freedom, mental privacy, mental integrity, psychological continuity, and fair access.[277] They suggest that the Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine could be an ideal platform to promote neurorights.[278]

The proposal for neurorights has garnered mixed reactions. The International Bioethics Committee has supported the importance of rights like cognitive liberty, mental privacy, mental integrity, and psychological continuity.[279] Nonetheless, the Panel for the Future of Science and Technology has a different point of view and affirms that the neurorights proposed by the Neurorights Foundation are not rights in the technical sense and reduce human identity to brain data.[280] They also cite concerns about the vagueness and premature nature of the constitutional reform in Chile to include neurorights. In this sense, the Panel for the Future of Science and Technology believes that the neurorights should be implemented at a subordinate level to supplement existing rights.[281]

5.7.2 Adaptation

An intermediary position has emerged among scholars proposing amendments to current legislation. This position focuses on creating supporting policies and adapting interpretations of existing rights to address the risks and impacts of neurotechnologies.

The Panel for the Future of Science and Technology proposes to amend the GDPR and the EU *AI Act*. According to them, the GDPR should explicitly include neurodata in Article 9. They also recommend that neurotechnologies be explicitly included in the EU *AI Act* as AI-related in Article 8.1, and to adapt the principles and frameworks for its use on neurotechnologies. In that sense, neurotechnology development could be regulated with a risk-based approach, with transparency and information requirements, and in doing so could also benefit from an extension of the AI data governance rules, and the ethical and safety standards embedded in the EU *AI Act*. Additionally, it would be possible to draw red lines for certain applications that pose significant issues such as involuntary manipulation of thoughts and emotions.[282]

277 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. pp. 3, 4, 21. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

278 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 8. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

279 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 48. https://doi.org/10.54678/QNKB6229

280 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. pp. 27, 51. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

281 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. pp. 32, 36. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

282 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. pp. 52, 66, 69. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

Bertoni and Ienca advocate for the use of Convention 108 and Convention 108+ as the basis of the regulation of neurotechnologies, which will allow the protections of privacy and data protection rights. They also call for the inclusion of neurodata in the definition of personal data and updated guidelines on data minimization and purpose limitation. They make this argument on the basis that the use of neurotechnologies challenges the traditional definition of privacy and data protection on the basis that it is not possible to "filter purpose-specific information in the dynamic flow of neural data."[283]

The UN Human Rights Council Advisory Committee suggests adopting soft law — non-binding guidance documents adapted to the challenges posed by neurotechnologies. These would provide clarity, set standards, and strengthen human rights protections in this area.[284]

On interpretative developments, the former UN Special Rapporteur Professor Ahmed Shaheed has stated that the right to freedom of thought can be used to address the challenges of neurotechnologies.[285] According to his report, freedom of thought should be interpreted to protect individuals from involuntarily revealing, manipulating, or penalizing their thoughts. This right, however, has some limitations and allows ordinary social influences, such as persuasion.[286]

Similarly, Ienca and Andorno propose a reconceptualization of traditional human rights such as the right to mental integrity. According to them, an action constitutes a threat to mental integrity when it meets three requirements:

- involve the direct access to and manipulation of neural signaling
- be unauthorized (i.e., must occur in the absence of the informed consent of the signal generator)
- result in physical and/or psychological harm

They also suggest that mental integrity rights should not be absolute and could allow for controlled, temporary violations if deemed beneficial. For instance, moral enhancement of persistent violent offenders could be allowed to reduce their prison time as long as the enhancement is done with informed consent and for the individual's benefit.[287]

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283 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 24, 25, 28. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

284 Human Rights Council Advisory Committee (2024, August 8). Impact, Opportunities and Challenges of Neurotechnology with Regard to the Promotion and Protection of all Human Rights: Report of the Human Rights Council Advisory Committee. United Nations Digital Library System. Par. 64. https://digitallibrary.un.org/record/4060417?ln=en%3Fln%3Den&v=pdf#files

285 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 18. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

286 Farahany, N. (2023b, March 14). Neuromarketing and the Battle for Your Brain. WIRED. https://www.wired.com/story/neuromarketing-philosophy-ethics/

287 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. pp. 8, 18, 20, 23. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

5.7.3 No new rights

Scholars who are against the recognition of new rights argue that it could lead to rights inflation which means labeling everything desirable as a human right,[288] and could later induce a neuro exceptionalism and neuroessentialism.[289] [290] This is worrisome as there is a lack of pre-existent scholarship and there is no moral obligation for positivisation.[291] According to Ienca and Bertoni human rights in the moral and legal sense are intertwined but are distinct, and proponents of new rights fail to understand that.[292]

Additionally, other scholars such as Alegre argue that there is no need for new rights as the rights claimed already exist within human rights law and that there is an effective protective shield. Alegre mentions, for instance, relevant legislation in the United Kingdom, which makes her worry about how to apply the framework properly.[293] [294] Other scholars consider that adding new rights could create legal uncertainty. For instance, the Panel for the Future of Science and Technology takes the example of mental integrity as a right already recognized in the Charter of Fundamental Rights. The Panel for the Future of Science and Technology asks: "Is the understanding developed under Article 3 transferable to the new right? Where are the limits? Would further aspects of integrity also need explicit regulation? What is the novelty?"[295]

6. Ethical Issues

Neurotechnology has been raising ethical questions for a long time. The term neuroethics was coined in 2002 by Safiner to define "the examination of what is right and wrong, good and bad about the treatment of, the perfection of, or unwelcome invasion of and worrisome manipulation of the human brain."[296] Since then, different approaches to ethical issues have emerged. For some authors, the classification is on safety and privacy, equity and justice,

288 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. p. 9. from https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

289 Bublitz, J.C. (31 Jan 2024): Neurotechnologies and Human Rights: Restating and Reaffirming the Multi- Layered Protection of the Person, The International Journal of Human Rights, https://doi.org/10.1080/13642987.2024.2310830

290 Bublitz, J.C. (2022) Novel Neurorights: From Nonsense to Substance. Neuroethics 15, 7. https://doi.org/10.1007/s12152-022-09481-3

291 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 27. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

292 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 19. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

293 Alegre, S. (2023, July 17). We Don't Need New "Neurorights" — We Need to Apply the Law. Center for International Governance Innovation. https://www.cigionline.org/articles/we-dont-need-new-neurorights-we-need-to-apply-the-law/

294 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 18. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

295 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 51. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

296 Ienca, M. (2021). Common Human Rights Challenges Raised by Different Applications of Neurotechnologies in the Biomedical Field. p. 28. https://www.researchgate.net/publication/356412675_COMMON_HUMAN_RIGHTS_CHALLENGES_RAISED_BY_DIFFERENT_APPLICATIONS_OF_NEUROTECHNOLOGIES_IN_THE_BIOMEDICAL_FIELD

and agency, autonomy and identity.[297] For Sang-Ho Yoo et al, the ethical aspects include humanity, dignity, personality and identity.[298] For UNESCO, it includes self-determination, freedom of thought, responsibility, privacy, personal and collective identity, fairness, trust, respect, reciprocity, and justice.[299] It is worth noting that for some authors the ethical aspects may come into tension depending on beliefs between Western and non-Western cultures.[300] In that sense, this section includes the most popular ethical issues.

6.1 Identify, integrity, and humanity

On the positive side, neurotechnology holds the potential to contribute to human flourishing while complying with the do-no-harm principle.[301] Nevertheless, neurotechnology can create threats to the personal identity and the authenticity of the self. Since the brain governs cognition, emotion, consciousness, and behavior — key aspects of what defines humanity[302] — any alteration to it warrants scrutiny. Therefore special attention is drawn to imposed memory modification, such as deleting or reconstructing past memories.[303] The brain can also develop obsessive thoughts or behavior that the person cannot control, with the effect of creating an impact on their identity.[304] Additionally, deep brain stimulation can disorient the mind and create a feeling of alienation as there is a form of subjugation of the person to the nanotechnology device. The implications for identity and authenticity are especially critical for children undergoing neurodevelopment. In such cases, it becomes challenging to distinguish whether certain traits or behaviors originate from the child or the neurotechnological device, further complicating ethical considerations.[305]

Neuro enhancement

Different scholars pay special attention to neuroenhancement. The idea of improving and optimizing one's self is not new and there are, according to the Panel for the Future of Science and Technology, good and bad reasons behind it. An enhancement increases performance and has an impact on individual happiness.[306] It is based on a self-determined

297 O'Shaughnessy, M. R., Johnson, W. G., Tournas, L. N., Rozell, C. J., & Rommelfanger, K. S. (2023). Neuroethics Guidance Documents: Principles, Analysis, and Implementation Strategies. Journal of Law and the Biosciences, 10(2). p. 8. https://doi.org/10.1093/jlb/lsad025

298 Yoo, S., Choi, K., Nam, S., Yoon, E., Sohn, J., Oh, B., Shim, J., & Choi, M. (2023). Development of Korea Neuroethics Guidelines. Journal of Korean Medical Science, 38(25). p. 5. https://doi.org/10.3346/jkms.2023.38.e193

299 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 47. https://unesdoc.unesco.org/ark:/48223/pf0000391074

300 O'Shaughnessy, M. R., Johnson, W. G., Tournas, L. N., Rozell, C. J., & Rommelfanger, K. S. (2023). Neuroethics Guidance Documents: Principles, Analysis, and Implementation Strategies. Journal of Law and the Biosciences, 10(2). p. 7. https://doi.org/10.1093/jlb/lsad025

301 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 11. https://unesdoc.unesco.org/ark:/48223/pf0000391074

302 Yoo, S., Choi, K., Nam, S., Yoon, E., Sohn, J., Oh, B., Shim, J., & Choi, M. (2023). Development of Korea Neuroethics Guidelines. Journal of Korean Medical Science, 38(25). pp. 4, 5. https://doi.org/10.3346/jkms.2023.38.e193

303 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 27. https://doi.org/10.54678/QNKB6229

304 Yoo, S., Choi, K., Nam, S., Yoon, E., Sohn, J., Oh, B., Shim, J., & Choi, M. (2023). Development of Korea Neuroethics Guidelines. Journal of Korean Medical Science, 38(25). p. 5. https://doi.org/10.3346/jkms.2023.38.e193

305 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 27, 28. https://doi.org/10.54678/QNKB6229

306 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 35. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

choice from a libertarian point of view and it is considered a stage of evolution from a utilitarian perspective. However, enhancement also challenges the limits of nature and the concept of normality in relation to the function of the body.[307]

In this sense, the use of neuroenhancement raises diverse ethical concerns. It can impact fairness in competitive environments, increasing social pressure to adopt it that can lead to coercion or discrimination.[308] This situation can raise particular challenges in hierarchical settings and in vulnerable groups such as children, individuals with mental disabilities, and captive populations. It can lead to putting at risk the idea of the inherent and equal dignity of all human beings by imposing a selection of the best and resurrecting the ethical problem of eugenics.[309]

6.2 Agency and autonomy

In theory, individuals should have the personal autonomy to fully control the use of neurotechnologies.[310] Literature on autonomy generally defines an autonomous action as one that involves intentionality, awareness, and the absence of external influences.[311] Nevertheless, since neurotechnologies can manipulate or alter cognitive functions or use closed-loop systems fed by AI, the degree of autonomy and agency of a person after the intervention is questioned.[312] [313] Furthermore, scholars also highlight how neurotechnologies could be employed to assess brain activity and evaluate an individual's autonomy, adding another layer of complexity to the issue.[314]

6.3 Equity and justice

There is an ethical problem regarding how neurotechnologies are accessed and distributed in society. UNESCO suggests that if neurotechnology contributes to human health, it should be distributed fairly on a global scale, with respect for collective decision-making, cultural heritage, and identity. However, this ideal is difficult to achieve in practice.[315]

Some groups of people due to their living conditions have a higher incidence of mental disorders and may experience a disparity in access to neurotechnologies. This is, for

307 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 34-36. https://doi.org/10.54678/QNKB6229

308 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 10. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

309 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 36-37. https://doi.org/10.54678/QNKB6229

310 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 9. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

311 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 28. https://doi.org/10.54678/QNKB6229

312 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. pp. 28-29. https://doi.org/10.54678/QNKB6229

313 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 34. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

314 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 30. https://doi.org/10.54678/QNKB6229

315 UNESCO (2024). First Draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. p. 13. https://unesdoc.unesco.org/ark:/48223/pf0000391074

instance, the case in Canada, where there are regional disparities in the availability of deep brain stimulation for movement disorders.[316] Additionally, respecting Indigenous data and individuals adds another layer of complexity, as specific cultural and legal considerations must be taken into account to ensure the lawful and ethical handling of such sensitive information. This situation is further exacerbated when access to neurotechnologies is limited to those who can afford them, creating inequities in treatment availability and further marginalizing vulnerable populations.[317] [318] [319]

Another ethical issue arises in the collection and processing of data for the development of neurotechnologies. While it is crucial to gather diverse data to reduce biases in technology, vulnerable populations are often susceptible to optimism bias. This can lead to errors in research and the premature deployment of technologies that may not be fully tested for broader applications.[320] Moreover, the sensitivity of the processed data increases the risk of stigmatization.[321]

These concerns highlight the need for caution, as emphasized by the Panel for the Future of Science and Technology, particularly regarding vulnerable groups such as children, neurodiverse individuals, and those with dementia. There is a strong call for a framework that examines the social impact of neurotechnologies, taking into account the power dynamics at play and ensuring that ethical standards are met to protect the rights and well-being of individuals.[322]

6.4 Safety and privacy

Safety and privacy are critical ethical issues in the realm of neurotechnology. Safety is crucial in the development of any technology but neurotechnologies pose unique challenges due to the potential for unauthorized access and manipulation of neurodata. Such intrusions could lead to a loss of control over one's body, thoughts, or mental processes, raising significant ethical concerns.[323]

316 Illes, J., Lipsman, N., McDonald, P. J., Hrincu, V., Chandler, J., Fasano, A., Giacobbe, P., Hamani, C., Ibrahim, G. M., Kiss, Z., Meng, Y., Sankar, T., & Weise, L. (2021). From Vision to Action: Canadian Leadership in Ethics and Neurotechnology. International Review of Neurobiology, 159, p. 245. https://doi.org/10.1016/bs.irn.2021.06.012

317 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 33. https://doi.org/10.54678/QNKB6229

318 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 8. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

319 Tesluk, J., Illes, J., & Matthews, R. (2017). First Nations and Environmental Neuroethics: Perspectives on Brain Health from a World of Change. In Oxford University Press eBooks. https://doi.org/10.1093/oso/9780198786832.003.0023

320 Illes, J., Lipsman, N., McDonald, P. J., Hrincu, V., Chandler, J., Fasano, A., Giacobbe, P., Hamani, C., Ibrahim, G. M., Kiss, Z., Meng, Y., Sankar, T., & Weise, L. (2021). From Vision to Action: Canadian Leadership in Ethics and Neurotechnology. International Review of Neurobiology, 159, p. 253. https://doi.org/10.1016/bs.irn.2021.06.012

321 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 69. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

322 Panel for the Future of Science and Technology (2024). The Protection of Mental Privacy in the Area of Neuroscience - Societal, Legal and Ethical Challenges. p. 34, 36. https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757807

323 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 10. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

In the case of privacy, one major issue is the possibility of mind reading and whether individuals are even aware when it occurs.[324] Scholars have studied these risks and their worries could be classified into three groups of rationales for protecting neurodata: neurodata is a special category of data due to its intimate nature, the potential invasiveness of mental privacy, and worries about the misuse of the obtained information.[325]

In terms of solutions, Bertoni and Ienca suggest using Chomskyan concepts to differentiate mental privacy in the broad sense from mental privacy in the narrow sense. The broad sense focuses on concerns like re-identification, cybersecurity risks, insecure data sharing, exploitation, and manipulation. These issues arise from the ability of neurotechnology to reveal correlations between neurodata and mental states, without necessarily decoding the actual content of those states. Meanwhile, the narrow sense of mental privacy concerns the direct access to and decoding of an individual's cognitive, affective, or conative processes. This distinction deepens the discussion around the risks of surveillance and unauthorized access to an individual's private mental life.[326]

7. What are regulators and authorities doing? Legal and ethical responses

Some organizations and countries have been debating and adopting possible legal and ethical solutions to the challenges brought by neurotechnologies. The following chart presents developments, as of November 2024, that include explicit neurotechnology regulations and policies. It does not include case laws or bills that expired or were taken out from parliamentary debate.

Country	Type of document	Date	Status	Content
Argentina	Bill (0339-D-2022)[327]	2022	In debate	Amendment of Article 145 on Probationary Freedom of the Federal Criminal Procedure Code of the Nation and its amendments. It adds the following text: "These methods include brain imaging techniques and any other type of neurotechnology that, based on data relating to brain structure and/or function, allows us to infer mental activity in all its aspects. They may only be used by court order and with the explicit consent of the person, who must be previously informed of their purposes and scope."

324 International Bioethics Committee (2021). Ethical Issues of Neurotechnology. UNESCO. p. 32. https://doi.org/10.54678/QNKB6229

325 Jwa, A. S., & Martinez-Martin, N. (2024). Rationales and Approaches to Protecting Brain Data: A Scoping Review. Neuroethics, 17(2). https://doi.org/10.1007/s12152-023-09534-1

326 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. pp. 11-13. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

327 Passo, M. F. (2022). Proyecto de Ley 0339-D-2022. Cámara de Diputados de la Nación Argentina. https://www4.hcdn.gob.ar/dependencias/dsecretaria/Periodo2022/PDF2022/TP2022/0339-D-2022.pdf

Country	Type of document	Date	Status	Content
Brazil	Bill N 522/2022[328]	2022	In debate	Amendment of the Brazilian General Data Protection Law to conceptualize neurodata and regulate its protection.
	Bill N 2174/2023[329]	2023	In debate	It establishes the rules and principles for the protection of fundamental rights related to the brain and the human nervous system, aiming to guarantee the protection and promotion of the neurorights of individuals.
	Bill PEC 29/ 2023 - Constitutional reform[330]	2023	In debate	Amendment of Article 5 of the Brazilian Constitution to add the following: "Scientific and technological development will ensure mental integrity and algorithmic transparency, in the terms of the law."
	Rio Grande do Sul PEC 298/2023 - Constitutional reform[331]	2024	Enacted	Amendment of Article 235 of the constitution establishing the protection of mental identity against research that affects the brain and its activity, without the individual's consent.
Chile	Law 21383 - Constitutional Reform[332]	2021	Enacted	Amendment to add a final paragraph to article N 19.1 of the Chilean Constitution: "Scientific and technological development will be at the service of people and will be carried out with respect for life and physical and mental integrity. The law will regulate the requirements, conditions, and restrictions for its use in people, and must especially protect the activity brain, as well as the information coming from it."
	Bill N° 578/ SEC/21[333]	2021	In debate	Introduces the protection of neurorights and mental integrity, and the development of research and neurotechnology.

328 Henrique Gaguim, C (2022). PL n.522/2022, Câmara dos Deputados. https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=2249221

329 Pereira, R.J. (2023). PL n.2174/2023, Câmara dos Deputados. https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=2286407&filename=Ultimo%20Despacho%20-%20PL%202174/2023

330 Randolfe, R. (2023). Proposta de Emenda à Constituição N° 29, de 2023. Senado Federal do Brasil https://legis.senado.leg.br/sdleg-getter/documento?dm=9386704&ts=1686688862951&disposition=inline

331 Burhalde Mua, C. T., & Caliendo Velloso da Silveira, P. A. (2024, January 5). Proteção ao neurodireito e à integridade mental na Constituição do RS. https://www.conjur.com.br/2024-jan-05/protecao-ao-neurodireito-a-integridade-mental-na-constituicao-do-rs/constituicao-do-rs/

332 Ministerio de Ciencia, Tecnología, Conocimiento e Innovación (2021, October 25). Ley 21383 - Firma electrónica modifica la Carta Fundamental para establecer el desarrollo científico y tecnológico al servicio de las personas. Biblioteca del Congreso Nacional de Chile. https://www.bcn.cl/leychile/navegar?idNorma=1166983

333 Girardi,G., Goic,C., Chahuán,J., Coloma,J. & De Urresti, A (2020). Proyecto de ley, iniciado en moción de los Honorables Senadores señor Girardi, señora Goic, y señores Chahuán, Coloma y De Urresti, sobre protección de los neuroderechos y la integridad mental, y el desarrollo de la investigación y las neurotecnologías. https://www.diarioconstitucional.cl/wp-content/uploads/2020/12/boletin-13828-19-nuroderechos.pdf

Country	Type of document	Date	Status	Content
France	French Charter for the Responsible Development of Neurotechnologies[334]	2022	Published	It establishes a commitment to protect, personal brain data, ensure the reliability, safety, and security of medical and non-medical devices, develop ethical and deontological communication, prevent abusive uses, applications, and malicious manipulations, and to take into account societal expectations.
	Law 2021-1017[335]	2021	Enacted	Amendment to Penal Code Art. 225-3 to prohibit discrimination based on the state of health using data from brain imaging techniques.
Mexico	Mexico City - Charter of Personal Rights in the Digital Environment: Good Practices[336]	2022	Published	It introduces a chapter on neurorights listing the rights to the preservation of personal identity, to the privacy of neurodata, to non-interference in freedom of decision, to equity in the improvement of brain capacity, and to protection against bias and discrimination.
	Bill - Constitutional reform[337]	2023	In debate	It orders Congress to advance legislation on artificial intelligence, cybersecurity, and neuro-rights.
	Bill - Constitutional reform[338]	2023	In debate	Amendment to the Constitutional reform to add a ninth paragraph to Article 4th of the Federal Constitution. This addition grants the right to individual identity, and physical and mental integrity.
	Bill[339]	2024	In debate	It introduces a general law on neurorights and neurotechnologies. It creates ten new rights and four criminal offenses.

334 Ministère de l'Enseignement supérieur et de la Recherche (2022). Charte de développement responsable des neurotechnologies. https://www.enseignementsup-recherche.gouv.fr/fr/charte-de-developpement-responsable-des-neurotechnologies-87964

335 L'Assemblée nationale. (2021) LOI n° 2021-1017 du 2 août 2021 relative à la bioéthique. Article 18. https://www.legifrance.gouv.fr/loda/id/LEGIARTI000043886053/2021-08-04/

336 Instituto de Transparencia, Acceso a la Información Pública, Protección de Datos Personales y Rendición de Cuentas de la Ciudad de México (2022). Carta de Derechos de la Persona en el Entorno Digital. https://www.infocdmx.org.mx/doctos/2022/Carta_DDigitales.pdf

337 Centro Competencia (2025, January 22). México: Las diversas iniciativas de regulación de la IA. https://centrocompetencia.com/mexico-las-diversas-iniciativas-de-regulacion-de-la-ia/

338 Hernández Pérez , M. E. (2023). Iniciativa con Proyecto de Decreto por la que se adiciona un noveno párrafo y se recorren los subsecuentes del Artículo 4; de la Constitución Política de los Estados Unidos Mexicanos. Gobernacion. http://sil.gobernacion.gob.mx/Archivos/Documentos/2023/08/asun_4588906_20230808_1690903141.pdf

339 Lagunes Soto Ruíz, A (2024). Iniciativa con proyecto de decreto por el que se expide la Ley General de Neuroderechos y Neurotecnologías y se reforman y adicionan diversas disposiciones en materia de neuroderechos y neurotecnologías. LXV Legislatura, Senadora Alejandra Lagunes Soto Ruíz. Congreso de la Unión de México. http://sil.gobernacion.gob.mx/Archivos/Documentos/2024/07/asun_4765214_20240717_1721235743.pdf

Country	Type of document	Date	Status	Content
Spain	Charter of Digital Rights[340]	2021	Published	It introduces a section called "Digital rights in the use of neurotechnologies" that includes: 1. The conditions, limits, and guarantees of implementation and use of neurotechnologies in people may be regulated by law with the purpose to: a) Guarantee each person's control over their own identity. b) Guarantee individual self-determination, sovereignty, and freedom in decision-making. c) Ensure the confidentiality and security of the data obtained or related to your brain processes and full control and disposition over them. d) Regulate the use of human-machine interfaces that may affect physical or mental integrity. e) Ensure that decisions and processes based on neurotechnologies are not conditioned by the provision of incomplete, unwanted, unknown, or biased data, programs or information. 2. To guarantee the dignity of the person, equality and non-discrimination, and in accordance where appropriate with international treaties and conventions, the law may regulate those assumptions and conditions of use of neurotechnologies that, beyond their therapeutic application, aimed at cognitive increase or the stimulation or enhancement of people's abilities.
United States	Minnesota HF 1904[341]	2023	In debate	It introduces an act relating to data privacy; establishing neurodata rights; modifying certain crimes to add neurodata elements; providing civil and criminal penalties.
	Colorado Act H.B. 24-1058[342]	2024	Enacted	Amendment to expands the definition of sensitive data of the *Colorado Privacy Act* to include biological data and neural data.
	California S.B. 1223[343]	2024	Enacted	Amendment to Section 1789.140 of the Civil Code to define sensitive personal information, and include consumer's neurodata, and define neural data to mean information that is generated by measuring the activity of a consumer's central or peripheral nervous system, and that is not inferred from non-neural information.

340 Secretaría de Estado de Digitalización e Inteligencia Artificial. (2021). Carta de Derechos Digitales. https://derechodigital.pre.red.es/documentos/140721-Carta_Derechos_Digitales_RedEs.pdf

341 H.F. 1904, 93d Leg., Reg. Sess. (Minn. 2023), Minnesota https://www.revisor.mn.gov/bills/text.php?number=HF1904&version=latest&session=93&session_number=0&session_year=2023

342 H.B. 24-1058, 74th Gen. Assemb., 2d Reg. Sess. (2024). Colorado https://leg.colorado.gov/sites/default/files/2024a_1058_signed.pdf

343 S.B. 1223, 2023-2024 Leg., Reg. Sess. (2024), California https://legiscan.com/CA/text/SB1223/id/2962687

Institutions	Type of document	Date	Content
OECD	OECD Recommendation on Responsible Innovation in Neurotechnology[344]	2019	It introduces nine principles for responsible neurotechnology innovation. These principles include responsible innovation to address health challenges, prioritization of safety, promotion of inclusivity, fostering of scientific collaboration, societal deliberation, capable oversight, and advisory bodies, among others.
Latin American Parliament	Model Neurorights Law for Latin America and the Caribbean[345]	2023	It suggests the legislation of the following rights: mental privacy, identity and autonomy personal, free will and self-determination, equitable access to cognitive augmentation, and protection from algorithmic biases, among others. Additionally, this model law creates a competent authority to oversee neurorights.
Organization of American States – Inter American Judicial Committee	Declaration of Inter-American Principles on Neurosciences, Neurotechnologies and Human Rights[346]	2023	The document presents a list of ten principles based on recognized human rights and opts for an approach to personal data by placing "Neural data as sensitive personal data" in principle 3. It is based on a previous declaration from 2021.[347] The Ibero-American Data Protection Network endorsed both declarations in 2023.[348]
UNESCO	Draft of a Recommendation on the ethics of neurotechnology[349]	ongoing work	This document will introduce values, principles and policy actions in different areas.
Global Privacy Assembly	Resolution on principles regarding the processing of personal information in neuroscience and neurotechnology[350]	2024	This resolution endorses existing data protection and privacy principles as core elements for ethical and lawful processing of personal information for neuroscience and neurotechnology. The principles include: lawful basis for processing and consent, purpose specification and use limitation, data minimisation, accuracy, transparency, security, proactive measures, data subject rights, accountability, high standard protection to special categories of data, ethical considerations, international cooperation, and proactive measures to support vulnerable groups' exercise of individual's rights.

344 The Organisation for Economic Co-operation and Development (2019). OECD Recommendation on Responsible Innovation in Neurotechnology. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm

345 Parlamento Latinoamericano y Caribeño (2023, May 20). Ley Modelo de Neuroderechos para América Latina y el Caribe. https://parlatino.org/wp-content/uploads/2017/09/leym-neuroderechos-7-3-2023.pdf

346 The Inter-American Juridical Committee (2021, January). Declaration of the Inter American Juridical Committee on Neuroscience, Neurotechnnologies and Human Rights: New Legal Challenges for the Americas. Organization of American States. https://www.oas.org/en/sla/iajc/docs/CJI-DEC_01_XCIX-O-21_ENG.pdf The Inter-American Juridical Committee (2023, March). Inter-American Declaration of Principles on Neuroscience, Neurotechnologies, and Human rights. Organization of American States. https://www.oas.org/en/sla/iajc/docs/CJI-RES_281_CII-O-23_corr1_ENG.pdf

347 The Inter-American Juridical Committee (2021, January). Declaration of the Inter American Juridical Committee on Neuroscience, Neurotechnnologies and Human Rights: New Legal Challenges for the Americas. Organization of American States. https://www.oas.org/en/sla/iajc/docs/CJI-DEC_01_XCIX-O-21_ENG.pdf

348 Red Iberoamericana de Protección de Datos. (2023, September 25). Declaración sobre neurodatos de la Red Iberoamericana de Protección de Datos. https://www.redipd.org/documento/declaracion-neurodatos-ripd.pdf

349 UNESCO (2024). First draft of a Recommendation on the Ethics of Neurotechnology (revised version): Working document as of 27 August 2024. https://unesdoc.unesco.org/ark:/48223/pf0000391074

350 Global Privacy Assembly (2024, November). Resolution on Principles Regarding the Processing of Personal Information in Neuroscience and Neurotechnology. 46th Closed Session of the Global Privacy Assembly. https://globalprivacyassembly.org/wp-content/uploads/2024/11/Resolution-on-Neurotechnologies.pdf

8. Looking to the future

Several trends have been identified for the development of neurotechnology over the next 10 to 20 years. Experts predict that neurotechnologies will become mainstream, with advancements enhancing sensor capabilities, augmentative functions, memory processing, diagnostic accuracy, and minimizing tissue damage.

Optimized brain-computer interfaces are expected to become the preferred means of interacting with computers, while the next generation of prostheses will be controlled by neurotechnologies capable of capturing motor intent directly from brain activity.[351] Additionally, sensor capabilities will improve, and non-invasive sensors ensuring minimal tissue damage will be developed. This will make an impact in the gaming industry by providing better interaction and inferences,[352] [353] and in neurotechnologies that use closed-loop systems. This could enrich sensory experiences that will contribute to personalized neuromodulation therapies and more autonomous use.[354]

Neurotechnologies are also expected to evolve to include advanced augmentative capabilities. They could restore movement, provide solutions to neurological diseases, increase learning speed, and more. Combined with AI technologies, neurotechnologies may amplify human capabilities, potentially outperforming individuals or AI systems alone.[355] [356]

Advancements in memory processing are also on the horizon. Neurotechnology is predicted to go beyond motor functions and include memory functions. There could be a possibility to preserve human memory in an external device[357] and work with synthetic memory to help with memory retrieval and information optimization in the brain.[358]

9. Conclusion

Neurotechnology represents a transformative force, poised to revolutionize fields such as healthcare, employment, and law enforcement, while simultaneously raising profound ethical, and legal challenges. This underscores the need for a balanced approach — one

351 Ienca, M., & Andorno, R. (2017, April 26). Towards New Human Rights in the Age of Neuroscience and Neurotechnology. BioMed Central. pp. 4, 5. https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-017-0050-1

352 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. pp. 24, 26. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

353 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 20. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

354 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 27. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

355 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 5. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

356 IEEE Brain (2020). Future Neural Therapeutics. Technology Roadmap White Paper Version 2. p. 19. https://brain.ieee.org/wp-content/uploads/2021/05/Future-Neural-Therapeutics-WP-V2.1.pdf

357 European Data Protection Supervisor, & Agencia Española de Protección de Datos (2024). TechDispatch #1/2024 - Neurodata. p. 20. https://www.edps.europa.eu/data-protection/our-work/publications/techdispatch/2024-06-03-techdispatch-12024-neurodata_en

358 Bertoni, E., & Ienca, M. (2024). The Privacy and Data Protection Implication of the Use of Neurotechnology and Neural Data from the Perspective of Convention 108. p. 4. https://rm.coe.int/expert-report-neuroscience/1680b12eaa

that embraces the benefits of neurotechnology while addressing its inherent risks and limitations. The ethical implications, ranging from the potential erosion of personal identity and authenticity to the exacerbation of social inequalities, demand careful consideration. Similarly, legal challenges, including questions about mental privacy, cognitive liberty, and fair trial rights, call for nuanced regulatory frameworks that are both forward-thinking and adaptable.

The evolution of neurotechnology requires a proactive and inclusive response that prioritizes human dignity, autonomy, and equity. Policymakers, researchers, and developers must collaborate to ensure that neurotechnology serves societal interests without compromising human rights. This entails not only addressing technical and regulatory gaps but also fostering public trust through transparency and accountability. The role of oversight bodies becomes critical in navigating these complexities and safeguarding the public interest.

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