Ana Maria D'Ávila Lopes (Brazil)
Maria Concepción Rayón Ballesteros (Spain)
Tamami Fukushi (Japan)
(Editors)

CHALLENGES FOR THE REGULATION OF NEUROTECHNOLOGY COMPANIES

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livraria DO ADVOGADO editora

LIVRARIA DO ADVOGADO EDITORA
Rua Riachuelo, 1334 s/104
90010-273 - Porto Alegre - RS
Fone: (51) 3225-3311
livraria@doadvogado.com.br
www.doadvogado.com.br

ISBN 978-85-9590-165-0

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico
UNIFOR
PPGD
Programa de Pós-Graduação em Direito Constitucional

International Cataloguing-in-Publication Data (CIP)

C494 Challenges for the regulation of neurotechnology companies / Ana Maria D'Ávila Lopes , Maria Concepción Rayón Ballesteros , Tamami Fukushi (editors) ; Aline Passos Maia ... [et al.]. – Porto Alegre : Livraria do Advogado, 2026.

201 p. ; 25 cm.

Includes bibliography.

ISBN 978-85-9590-165-0

1. Law - Neuroscience. 2. Neurotechnology - Human Rights. 3. Neurotechnology Companies. 4. Neurotechnology - Governing. 5. Neurotechnologies - Mental Health in Childhood. I. Lopes, Ana Maria D'Ávila. II. Ballesteros, Maria Concepción Rayón. III. Fukushi, Tamami. IV. Maia, Aline Passos.

CDU 34:616.8

Index to systematic catalog:

1. Law - Neuroscience 34:616.8

(Librarian in charge: Sabrina Leal Araujo – CRB 8/10213)

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livraria DO ADVOGADO *editora*

Porto Alegre, 2026

Cover, graphic design and layout of
Livraria do Advogado Editora

Cover image of
freepik.com/free-photo/scientist-researcher

Financing
Chamada CNPq nº 14/2023 - Apoio a Projetos Internacionais de Pesquisa Científica, Tecnológica e de Inovação

Edition of
Comércio de Livros dos Advogados Ltda.
Livraria do Advogado Editora
Rua Riachuelo, 1334 s/104
90010-273 Porto Alegre RS
Fone: (51) 3225.3311
livraria@doadvogado.com.br
www.doadvogado.com.br

Printed in Brazil

— Preface —

The IV Seminar of the International Network on Neurolaw and Human Rights (www.neurorights.com.br) was held at the University of Fortaleza (Brazil) on October 27, 28 and 29, 2025. The Network, created in 2021 and officially launched in October 2022, is composed of researchers from the Universidade de Fortaleza (UNIFOR), Universidad Austral de Chile (UACH), Universidad Externado de Colombia (UExternado), Pontifícia Universidade Católica de Rio Grande do Sul (PUCRS) and Institute of Education and Research (INSPER). The Network's activities are currently funded by UNIFOR, through the Call for Proposals for the Support Program for Research Teams n. 66/2024 of the Vice-Rectory of Research of the University of Fortaleza (VRP/UNIFOR), as well as by the National Council for Scientific and Technological Development (CNPq), a Brazilian federal agency for research promotion, through the Call CNPq/MCTI/FNDCT n. 18/2021 and the Call for Support for International Scientific, Technological and Innovation Research Projects n. 14/2022.

The IV Seminar held thanks to the financial support of Call n. 39/2024 (ARC) of the CNPq, and it was one of the Network's academic activities. The Network also conducts research and teaching activities in the field of Neurolaw, in partnership with other Brazilian and international academic institutions.

At the 2025 Seminar, the chosen theme was "Impacts, regulation and challenges of neurotechnology companies", with the participation, both in person and virtually, of more than 30 researchers from different countries, notably highlighting the participation of Professor Marcello Ienca, from Technologial University of Munich (Germany who gave the opening conference).

This book brings together some of the lectures given during the IV Seminar as a contribution to the academic debate and to support legislative initiatives and judicial decisions that have been growing significantly, with the objective of ensuring the protection of humanity's future.

Ana Maria D'Ávila Lopes
Law Professor at the University of Fortaleza (Brazil)
Coordinator of the International Network of Neurolaw and Human Rights

— About the authors —

ALINE PASSOS MAIA

Professor of Law at the Center of Legal Sciences of the University of Fortaleza (Brazil). PhD in Labor Law from the University of Salamanca, Spain. Master's degree in Labor Law from the University of Salamanca, Spain. alinepmaia@unifor.br

ANA MARIA D'ÁVILA LOPES

Full Professor of Law at the University of Fortaleza (Brazil). Post-Doctorate in Law from the University of Auckland. PhD in Law from the Federal University of Minas Gerais. Research Productivity Fellow (PQ/CNPq-Brazil). anadavilalopes@unifor.br

ANTONIO JORGE PEREIRA JÚNIOR

Full Professor of the Master's and Doctoral Program in Constitutional Law at the University of Fortaleza. Doctor, Master's, and Bachelor's degree in Law from USP. Winner of the Jabuti Prize 2012, Law category. antoniojorge2000@gmail.com

CAMILA PINTARELLI

Post-Doctorate in Law (University of Coimbra). Member of the Global Future Council on Neurotechnology and of the Global Regulatory Innovation Platform (GRIP), both from World Economic Forum; State Attorney and advocate for the constitutional reform of neurorights in Brazil.

DENISE ALMEIDA DE ANDRADE

Ph.D. and a Master's degree in Constitutional Law. She completed postdoctoral research in Political and Economic Law and is currently a postdoctoral researcher in Law at the Faculty of Law of the Federal University of Ceará (UFC), funded by CAPES. She is a Professor in both the LL.M. program and the undergraduate Law program at Universidade Christus and a Professor at FGVLaw São Paulo. She is also Co-Coordinator of the CNPq Research Group Women and Democracy. Email: andradedenise@hotmail.com

FRANCISCO LUCIANO LIMA RODRIGUES

Full Professor of the Master's/Doctorate Graduate Program in Constitutional Law at the University of Fortaleza. Associate Professor at the Faculty of Law of the Federal University of Ceará. Judge of the Court of Justice of the State of Ceará. PhD in Law from the Federal University of Pernambuco, with a research internship at the Faculty of Law of the University of Lisbon Portugal. lucianolima@unifor.br

FELIPE PAREDES

Associate Professor at the Austral University of Chile (Chile). Master and PhD in Law from the Pompeu Fabra University (Spain). felipe.paredes@uach.cl

GABRIELLE BEZERRA SALES SARLET

Lawyer, graduated and holds a master's degree in Law from the Federal University of Ceará (UFC). Specialist in neuroscience and behavioral sciences from the Pontifical Catholic University of Rio Grande do Sul (PUCRS). PhD in Law from the University of Augsburg (UNIA) in Germany and postdoctoral fellow at the University of Hamburg and the Pontifical Catholic University of Rio Grande do Sul (PUCRS). CNPq Productivity Researcher. Coordinator of the Law and Artificial Intelligence Research Group (GDIA/INSPER). Associate Professor of the Law Course at the Institute of Education and Research (INSPER). Full member of the National Council for Data Protection and Privacy (CNPD) and the National Technical Chamber of Ethics and Investigation of the National Transplant System (SUS). President of the Rio Grande do Sul regional branch of the Brazilian Society of Bioethics (SBB). Member of the Intersectoral Commission on Science, Technology and Pharmaceutical Assistance (CICTAF) of the National Health Council (CNS). gabriellebezerrasales@gmail.com

JANNA DA NÓBREGA SOUZA

Assistant Professor at the University of Jaén (Spain). PhD from the University of Murcia. Master's degree from the Carlos III University of Madrid. jda@ujaen.es

LARISSA MACIEL DO AMARAL

Professor at the University of Fortaleza and Christus University Center (Brazil). Master in law from the Federal University of Ceará. PhD in Business Administration from the University of Fortaleza. Lawyer at Rabb Carvalho Advocacia. larissaamaral@unifor.br

MARÍA CONCEPCIÓN RAYÓN BALLESTEROS

Professor of Law at the Complutense University of Madrid (Spain). Lawyer of the Bar Association of Madrid. Mediator registered with the Ministry of Justice. PhD in Law and Licentiate in Political Science and Administration. mariaconcepcionrayon@gmail.com

MONICA SAPUCAIA MACHADO

Ph.D. and a Master's degree in Political and Economic Law from Universidade Presbiteriana Mackenzie, with her degrees formally recognized by Universidade Nova de Lisboa. She also holds a postgraduate degree in Public Administration from Fundação Getulio Vargas and a Bachelor of Laws (LL.B.) from Pontifícia Universidade Católica do Rio de Janeiro. She is a tenured Professor and Program Director of the Professional Master's Program in Law at the Brazilian Institute of Education, Development and Research (IDP). She serves as Co-Leader of the CNPq Research Group Women, Income, and Democracy, conducting interdisciplinary research at the intersection of gender equality, public policy, technological transformation, and social justice. Email: monica.machado@idp.edu.br

PATRÍCIA MOURA MONTEIRO CRUZ

Master's and PhD Candidate in Constitutional Law at the University of Fortaleza. Scholarship Holder and Professor of Undergraduate and Postgraduate Lato Sensu in Law at UNIFOR. patriciamoura@unifor.br

RAQUEL PASSOS MAIA

PhD candidate in Law at the Faculty of Law of the University of Lisbon (Portugal). Master in Constitutional Law at the Faculty of Law of the University of Lisbon. Scholarship holder of the Foundation for Science and Technology-FCT. raquelpmaia13@gmail.com

RENATO VILARDO DE MELLO CRUZ

Master's Student in Law and Conflict Management at the University of Fortaleza. State Attorney of Ceará and Lawyer. renatovmcruz@gmail.com

SEBASTIÁN SMART

Senior Research Fellow in Access to Justice, Law and Technology at Anglia Ruskin University (Cambridge, United Kingdom). PhD in Latin American Studies and Human Rights from University College London, as well as an MA in Human Rights from the same institution. sebastian.smart@aru.ac.uk

TAMAMI FUKUSHI

Professor at the Faculty of Human Welfare of the Tokyo Online University (Japan). PhD in Behavioral Science from the Hokkaido University Japan. BA in Physical Education from the Nara Women's University Japan. fukushi.tamami@internet.ac.jp

THAMMY ISLAMY CARLOS BRITO

Ph.D. candidate and holds a Master's degree in Law, Access to Justice, and Development from Universidade Christus. She is currently pursuing a postgraduate specialization in Corporate Compliance and Integrity at Pontifícia Universidade Católica de Minas Gerais (PUC Minas). She also holds a specialization in Public Administration from PUC Minas, a specialization in Law, Technology, and Innovation in Data Protection from Universidade de Fortaleza (UNIFOR), and a specialization in Public Law with an emphasis on Public Management from Faculdade Damásio de Jesus. Email: thammybritto@hotmail.com

VIVIANE CEOLIN DALLASTA DEL GROSSI

PhD in Human Rights from the University of São Paulo (USP). Master of Human Rights from USP. Master in Criminology and Penal Execution from Pompeu Fabra University (Interinstitutional degree from the University of Girona and the Autonomous University of Barcelona - Barcelona, Spain, 2014). Postgraduate degree in Public Law, with an emphasis on International Human Rights Law. Member of the Ethics, Human Rights and Artificial Intelligence Research Group (EDHIA/ENADPU/DPU). She was a UNESCO researcher for the implementation of the Recommendation on Ethics and AI in Brazil, 2025. Federal Public Defender since 2009.ORCID: https://orcid.org/0000-0003-3104-0091. E-mail: viviane.dallasta@dpu.def.br

— Contents —

— 1 —

Regulation of neurotechnology: global trends before and after OECDs recommendation

TAMAMI FUKUSHI[1]

Introduction

The concept of Brain-Computer Interface (BCI) or Brain-Machine Interface (BMI), which forms the foundation of neurotechnology, was proposed over half a century ago (Vidal, 1973). Since then, trial and error have been repeated, progressing from basic research using monkeys or rodents to clinical studies involving humans. As a result, not only methodologies for measuring and analyzing neural activity and mechanisms for translating this information into device control have advanced, but information processing technologies and devices for measuring neural activity have also become more sophisticated, smaller, and less invasive. Consequently, various products and services utilizing neurotechnology are approaching the criteria required for implementation in the real world (Lebedev et al., 2006; Peska and Mamchur, 2023). The next 50 years —particularly the immediate decade— can be described as a phase focused on refining technologies for clinical application and addressing clinical challenges to develop the standard for medical devices (Gao et al., 2020; also see clinical trial information on Neuralink's device https://clinicaltrials.gov/study/NCT06429735). Simultaneously, expectations for market expansion and investment

[1] Professor at the Faculty of Human Welfare of the Tokyo Online University (Japan). PhD in Behavioral Science from the Hokkaido University Japan. BA in Physical Education from the Nara Women's University Japan. fukushi.tamami@internet.ac.jp

opportunities are rising (for example, Rao, 2024, also see https://www.precedenceresearch.com/brain-computer-interface-market). On the other hand, when cutting-edge technologies transition from laboratories to society, principles of safety assurance and beneficiary protection are typically extended to diverse social contexts. Neurotechnology is no exception, and in the 2020s, discussions on ethical challenges accompanying its societal implementation have intensified (International Bioethics Committee of UNESCO, 2021; Nuffield Council 2024; United Nation Human Rights Council, 2025). In this paper, the author surveys relevant activities conducted by international organizations around the time of publication of the OECD Recommendation (2019), which triggered such discussions on responsible governance for neurotechnology implementation. It examines the evolution of debates surrounding neurotechnology regulation from a neuroethics perspective and explores the underlying context.

1. Outline of OECD Recommendation on neurotechnology

The Organisation for Economic Co-operation and Development (OECD) was established with the mission "to deliver greater well-being worldwide by advising governments on policies that support resilient, inclusive and sustainable growth," building upon its predecessor, the Organisation for European Economic Co-operation (OEEC), which administered the post-World War II European Recovery Program (Marshall Plan). Based on this historical background, the OECD has undertaken activities with enduring international impact, such as advocating The Polluter Pays Principle (PPP) and implementing the Programme for International Student Assessment (PISA). It also engages in international politics by collaborating with the policy-making communities of advanced nations through bodies like the G7 and G20.

The Recommendation of the Council on Responsible Innovation in Neurotechnology, prepared by the Committee for Scientific and Technological Policy (CSTP) in 2019, provided guidance for anticipating and addressing the ethical, legal, and societal challenges raised by new technologies while promoting innovation in neurotechnology. This recommendation was compiled as the outcome of the "Neurotechnology and Society" initiative conducted by the Working Party on Biotechnology, Nanotechnology and Converging Technologies (BNCT) from 2015 to 2019. Prior to this initiative, the OECD Working Party on Biotechnology discussed governance frameworks for neuroscience research and innovation related to Alzheimer's disease, along with national best practices, within the project "Healthy Ageing and Biomedical Innovation for Dementia and Alzheimer's disease" (OECD, 2015). That framework activity clarified the need to address how to advance open innovation in neurotechnology as a cutting-edge science and technology, leading to the launch of the "Emerging Technologies and the Brain" project. The activities of this project integrated with discussions on ethical, legal and social issues (ELSI) of neurotechnology conducted in OECD member countries, academic research on neuroethics including the activity of Responsible Research and Innovation (RRI) from the Ethics and Society subproject of the Human Brain Project (HBP) in Europe (Salles et al., 2019) and progressed the discussion to develop basic concept of the recommendations, leading to the activities of "Neurotechnology and Society" (OECD, 2017; Garden and Winickoff, 2018). The recommendations were also influenced by the OECD's concurrent work on anticipa-

tory innovation governance (OECD Working Papers on Public Governance, 2020), and compiled following expert meetings (Garden and Winickoff, 2018) and dialogues with industry (Garden et al., 2019). The recommendations advocate promoting innovation while proactively addressing the novel ethical, legal, and societal challenges posed by neurotechnology and ensuring safety, comprising nine key areas, each with subitems detailing actions and actors needed for their implementation.

a) Promote responsible innovation in neurotechnology to address health challenges (6 subitems).

b) Prioritise assessing safety in the development and use of neurotechnology (4 subitems).

c) Promote the inclusivity of neurotechnology for health (3 subitems).

d) Foster scientific collaboration in neurotechnology innovation across countries, sectors, and disciplines (4 subitems).

e) Enable societal deliberation on neurotechnology (5 subitems).

f) Enable the capacity of oversight and advisory bodies to address novel issues in neurotechnology (5 subitems).

g) Safeguard personal brain data and other information gained through neurotechnology (7 subitems).

h) Promote cultures of stewardship and trust in neurotechnology across the public and private sector (5 subitems).

i) Anticipate and monitor the potential unintended use and/or misuse of neurotechnology (4 subitems).

This recommendation was the first to be drafted and published by an international organization with influence in global politics, having secured membership from a certain number of nations. It served as a guiding principle to shift the sporadic discussions conducted by individual countries—identifying ethical concerns regarding neurotechnology, listing challenges associated with its societal implementation, organizing key issues, and outlining possible actions stakeholders should take—toward "formulating and implementing an international, concrete action plan for addressing these challenges. One should note that the general definition of an *OECD* Recommendation is: "*OECD legal instruments which are not legally binding but practice accords them great moral force as representing the political will of Adherents. There is an expectation that Adherents will do their utmost to fully implement a Recommendation. Thus, Members which do not intend to do so usually abstain when a Recommendation is adopted, although this is not required in legal terms.*" In other words, while lacking legal binding force, appropriate implementation of the recommendations carries a moral responsibility for member countries, and the OECD conducts surveys on implementation status. As introduced later, BNCT conducted a survey on the status of implementation of the Neurotechnology Recommendation starting in 2024.The following chapters will overview pioneering initiatives and international trends using major reports published both before and after the 2019 Recommendation as examples.

2. International trends in neurotechnology regulation: before the OECD recommendation in 2019

Figure 1 indicates chronological listing of major examples of reports, recommendations, and other documents published by international organizations from 2002, when neuroethics was declared an academic field, through 2025.

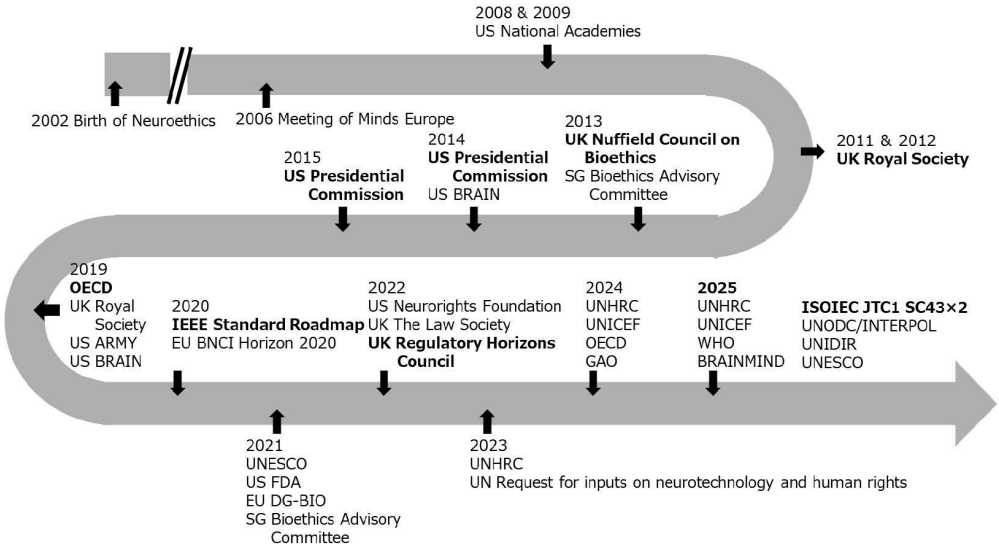

Figure 1

Policy reports, Consultation papers and Recommendations Relevant to Neurotechnology Regulation

While more organizations have frequently produced and published reports since the 2019 OECD recommendation, several institutions had already sounded the alarm about the various problems this technology could bring to human society and urged national-level responses, before the societal implementation of neurotechnology became a reality (also see Table 1). Representative examples highlighted in bold in the figure are outlined below.

2.1. Brain Waves Modules published by the Royal Society (UK)

The Royal Society is the United Kingdom (UK)'s oldest academic society. Alongside supporting scientific research and activities to deepen public understanding, it functions to advise the UK government on science and technology policy. Between 2011 and 2012, the Royal Society investigated what neuroscience could offer society at that time and the necessary measures required to deliver these benefits to society and published a four-part report compiled.

Part 1 (The Royal Society, 2011) consisted of reports on neuroscience research and cutting-edge technologies at the time, along with a collection of expert essays addressing the ethical issues arising when these technologies are introduced into society. It covered cutting-edge research and technologies such as lie detection using brain imaging, cognitive enhancement, BMI, transcranial magnetic stimulation, consciousness research, and neuroeconomics. It also addressed the risks and benefits of

these technologies, ethical issues, their relationship to policy, and governance in research and development. The report served as a background paper, underpinning the concerns and recommendations presented in subsequent reports produced by working groups that ad hoc recruited experts from each field.

Part II (The Royal Society, 2011) synthesized four recommendations for education professionals based on insights into how neuroscience could transform education and lifelong learning. The report expresses concern about the "Neuromyth" concept proposed by the OECD in the early 2000s (OECD, 2002). While acknowledging that neuroscientific findings contribute to understanding human brain development related to learning, the report cautioned against the simplistic application of such findings to school education, the education industry, and lifelong learning. It also recommended enhancing educators' understanding of neuroscience.

a) Neuroscience should be used as a tool in educational policy.

b) Training and continued professional development should include a component of neuroscience relevant to educational issues, in particular, but not restricted to, Special Educational Needs.

c) Neuroscience should inform adaptive learning technology.

d) Knowledge exchange should be increased.

In Part III (The Royal Society, 2011), the authors analyzed the technological assessment and human rights/legal implications of neuroscience research (particularly neuropharmacology) and the potential military application of neurotechnology. The report compiled policy recommendations targeted at the research community, governments, and the international community. A key feature of this report is its proposal for actions targeting multiple and specific stakeholders. These recommendations were believed to have influenced subsequent reports by international organizations.

a) There needs to be fresh effort by the appropriate professional bodies to inculcate the awareness of the dual-use challenge among neuroscientists at an early stage of their training.

b) The UK government should publish a statement on the reasons for its apparent recent shift in position on the interpretation of the CWC's law enforcement provision.

c) The UK government, building on the horizon scanning activity conducted by the Defence Science and Technology Laboratory (Dstl) and the Home Office Centre for Applied Science and Technology, should improve links with industry and academia to scope for significant future trends and threats posed by the applications of neuroscience.

d) The prioritisation and opportunity costs (i.e., in diverting support from alternative social applications of neuroscience) associated with neuroscience research into enhancement and degradation technologies for military use or civilian law enforcement should be subject to ethical review and should be as transparent as possible.

e) Countries adhering to the CWC (States Parties) should address the definition and status of incapacitating chemical agents under the CWC at the next Review Conference in 2013.

f) In addition to the Review Conference process, States Parties should initiate informal intergovernmental consultation on the status of incapacitating chemical agents under the CWC.

g) The implementing bodies of the Biological Weapons Convention (BWC) and CWC should improve coordination to address convergent trends in science and technology with respect to incapacitating chemical agents.

h) Neuroscience should be considered a focal topic in the science and technology review process of the BWC because of the risks of misuse for hostile purposes in the form of incapacitating weapons.

i) There should be further study, by bodies such as World Medical Association, on the legal and ethical implications of biophysical degradation technologies (such as directed energy weapons) targeted at the central nervous system.

j) Governments, medical associations and other professional bodies in the field of medicine should ensure that access to information about the possible risks of using cognitive enhancement drugs is available to military personnel and is as transparent as possible.

Part IV (The Royal Society, 2012) evaluated the impact of neuroscience findings on legal procedures and interpretations of law in the real world. While concluding that the neuroscience per se would not change the core legal concepts (such as responsibility), the report made the following recommendations to enhance communication between legal experts and neuroscientists regarding relevant scientific discoveries, and to improve human resource development and research capabilities:

a. An international meeting should take place every three years to bring together those working across the legal system with experts in neuroscience and related disciplines. The aim of this meeting should be to discuss the latest advances in areas at the intersection of neuroscience and the law to identify practical applications that need to be addressed.

b. The systems used by legal professionals to identify, access and assess the quality of expertise in specific scientifi c areas should be reviewed by the judiciary and the Bar Council to ensure the latest advice is made available. This should be carried out in consultation with learned societies such as the British Neuroscience Association, and other specialist societies as appropriate.

c. University law degrees should incorporate an introduction to the basic principles of how science is conducted and to key areas of science such as neuroscience and behavioural genetics, to strengthen lawyers' capacity to assess the quality of new evidence. Conversely, undergraduate courses in neuroscience should include the societal applications of the science.

d. Relevant training should be made available where necessary for judges, lawyers and probation officers. This should count towards Continual Professional Development (CPD) requirements for lawyers, and for judges might be administered through the Judicial College's programme of seminars.

Further research isneeded on areas including:

i. The National Institute for Health Research (NIHR) should encourage neuropathology studies to characterise Non-Accidental Head Injury (NAHI) and distinguish it from accidental or natural causes.

ii. The Economic and Social Research Council (ESRC) should encourage studies into the relative efficacy of different models of risk assessment in the context of probation, and a possible role for neuroscience to be used in combination with existing approaches.

2.2. Novel neurotechnologies: intervening in the brain published by Nuffield Council on Bioethics (UK)

The Nuffield Council on Bioethics is an independent think tank established in 1991 by the Nuffield Foundation to conduct research on ethical issues in biomedi-

cine. Since 1994, it has been funded not only by the Nuffield Foundation but also by the Wellcome Trust and the Medical Research Council in the UK. Thus, their research findings hold significant influence over stakeholders in the UK biomedical research sector and science and technology policy. This report examined the ethical and societal issues arising from the development and use of new technologies involving brain interventions, considering both medical and non-medical applications. It identified concerns and corresponding measures to be taken, with smaller recommendations subdivided into six major headings.

a) Responsible research governance (9 subitems).

b) Effective and proportionate oversight (7 subitems).

c) High standards of care for patients (4 subitems).

d) Making existing evidence transparent and accessible (5 subitems).

e) Protecting the interests of users in non-therapeutic contexts (4 subitems).

f) Responsible communication (4 subitems).

2.3. Gray Matters published by the Presidential Commission for the Study of Bioethical Issues (US)

During the Obama administration in the United States (US), the Presidential Commission for the Study of Bioethical Issues published a two-part report on neurotechnology. The first volume emphasizes the importance of integrating ethics into neuroscience research within the US BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies), a national effort to advance neuroscience research. It outlined four key recommendations for necessary actions to achieve this integration.

a) Integrate Ethics Early and Explicitly Throughout Research.

b) Evaluate Existing and Innovative Approaches to Ethics Integration.

c) Integrate Ethics and Science through Education at All Levels.

d) Explicitly Include Ethical Perspectives on Advisory and Review Bodies.

In Part II, the commission members reviewed the current state of neuroscience research and development and outlined 13 recommendations for ethically advancing its societal applications.

a) Prioritize Existing Strategies to Maintain and Improve Neural Health.

b) Prioritize Treatment of Neurological Disorders.

c) Study Novel Neural Modifiers to Augment or Enhance Neural Function.

d) Ensure Equitable Access to Novel Neural Modifiers to Augment or Enhance Neural Function.

e) Create Guidance About the Use of Neural Modifiers.

f) Responsibly Include Participants with Impaired Consent Capacity in Neuroscience Research.

g) Support Research on Consent Capacity and Ethical Protections.

h) Engage Stakeholders to Address Stigma Associated with Impaired Consent Capacity.

i) Establish Clear Requirements for Identifying Legally Authorized Representatives for Research Participation.

j) Expand and Promote Educational Tools to Aid Understanding and Use of Neuroscience within the Legal System.

k) Fund Research on the Intersection of Neuroscience and the Legal System.

l) Avoid Hype, Overstatement, and Unfounded Conclusions.

m) Participate in Legal Decision-Making Processes and Policy Development.

These reports preceded the OECD's efforts and exerted a certain influence on the formulation of its recommendations. They emphasized the importance of proactively gathering information on the technological advances and implementation areas of neurotechnology. Furthermore, they attempted to systematically anticipate the various ethical issues arising from the implementation of these technologies —including those not yet pressing concerns at that stage— and explore possible actions to address them. Indeed, reports from the Presidential Commission of the US and the Nuffield Council were explicitly referenced and cited in the reports published during the OECD's recommendation development process (OECD, 2017; Garden et al., 2019). Furthermore, the involvement of multiple external experts and the identification of stakeholders and actors described in the OECD's recommendations showed clear influence from the methodology used in the Royal Society's reports. Thus, from the perspective of shaping international rules, while US and UK initiatives have led to some direct national-level neurotechnology regulations (Department of Health and Human Services, Food and Drug Administration, Center for Devices and Radiological Health, 2021) and others have not, they can be evaluated as having played a role in pioneering the organization of key issues and charting the course for discussion. Nevertheless, ethical and governance discussions surrounding neurotechnology in this era were based on predictions grounded in the technological standards of the time, as the development of neurotechnology as an industry in the real world had not yet caught up. It must be noted that addressing problems that subsequently arose in the real world—such as providing psychological care for participants after the removal of BCI devices following clinical trials—may require new considerations based on accumulated case studies (Gilbert et al., 2023; Vooijs et al., 2025).

	Organization/Project	Title of Publication	Publication Year	Publication URL
1	Meeting of Minds Europe	37 Recommendations on Brain Science European Citizens' Assessment Report	2006	N/A
2	National Research Council	Emerging Cognitive Neuroscience and Related Technologies	2008	https://doi.org/10.17226/12177
3	National Research Council	Opportunities in Neuroscience for Future Army Applications	2009	https://doi.org/10.17226/12500
4	**Royal Society**	**Brain Waves Module 1: Neuroscience, society and policy**	2011	https://royalsociety.org/-/media/policy/publications/2011/4294974932.pdf
5	**Royal Society**	**Brain Waves Module 2: Neuroscience: implications for education and lifelong learning**	2011	https://royalsociety.org/-/media/policy/publications/2011/4294975733.pdf

6	**Royal Society**	**Brain Waves Module 3: Neuroscience, conflict, and security**	2012	https://royalsociety.org/-/media/policy/projects/brain-waves/2012-02-06-bw3.pdf
7	**Royal Society**	**Brain Waves Module 4: Neuroscience and the law**	2012	https://royalsociety.org/-/media/policy/projects/brain-waves/brain-waves-4.pdf
8	**Nuffield Council on Bioethics**	**Novel Neurotechnologies: Intervening in the Brain**	2013	https://www.nuffieldbioethics.org/assets/pdfs/Novel-neurotechnologies-report.pdf
9	Bioethics Advisory Committee Singapore	Ethical, Legal and Social Issues in Neuroscience Research.	2013	https://isomer-user-content.by.gov.sg/154/593af6fd-0436-4c56-baf0-f705ea5036e9/neuroscience-cp.pdf
10	Brain Research through Advancing Innovative Neurotechnologies Working Group	BRAIN 2025 A Scientific Vision	2014	https://braininitiative.nih.gov/sites/default/files/documents/brain2025_508c_2.pdf
12	**Presidential Commission for the Study of Bioethical Issues**	**GRAY MATTERS Vol.1 Integrative Approaches for Neuroscience, Ethics, and Society**	2014	repository.library.georgetown.edu/bitstream/handle/10822/709231/Gray Matters Vol 1.pdf?sequence=1
13	**Presidential Commission for the Study of Bioethical Issues**	**GRAY MATTERS Vol.2 Topics at the Intersection of Neuroscience, Ethics, and Society**	2015	https://repository.library.georgetown.edu/bitstream/handle/10822/712920/Gray%20Matters%20Vol%202.pdf
15	OECD Committee for Scientific and Technological Policy	Recommendation of the Council on Responsible Innovation in Neurotechnology	2019	https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0457

Table 1
Examples of Policy Reports, Consultation Papers, and Recommendations Relevant to Neurotechnology Regulation (Accessed December 10, 2025)

Note. Part of this list was updated from Table 1 of Fukushi (2024).

3. Horizon scanning of neurotechnology after OECD recommendation-relevant activities by international organization

The preceding chapters introduced the OECD's 2019 recommendation and the initiatives by US and UK organizations that influenced it. Now in 2025, it is the time to consider how did the OECD's recommendation influence the global response, particularly among member countries, regarding policy responses to neurotechnology? In this chapter, the author will introduce the relevant activities in 202s.

First, the author summarize the actions conducted by OECD. The OECD BNCT organized multiple awareness-raising events (for example, see Committee on Bioethics of the Council of Europe, 2021), aimed at disseminating the recommendation and encouraging member countries to respond. Furthermore, to raise awareness and encourage collaboration with the private sector, they held joint events with academic organizations and industrial community such as BrainMind (see BrainMind's websites https://brainmind.org/neuroethics-paris and https://brainmind.org/45856332578/summit2023). These stemmed from the fact that progress in the private sector lags behind that in the public sector regarding implementing the recommendations, and the increasing importance of regulatory measures by industry as neurotechnology R&D has shifted decisively from academia to industry and R&D investment has grown significantly (Winickoff, 2021; Pfotenhauer et al., 2021). Indeed, several reports indicate that the period when the OECD actively engaged industry coincided

with increased venture capital investment in neurotechnology for medical purposes (for example, Dhawan et al., 2025). Following this awareness-raising phase, the OECD BNCT began surveying the implementation status of the recommendation in 2024, developing and publishing a Toolkit to clarify survey methodologies (OECD, 2025). Considerable member states of the European Parliament and the Organization of American States advanced their legal frameworks around the time this survey was taking shape. Discussions on the ethical use and dissemination of neurotechnology are also intensifying within international organizations outside the OECD, such as the agencies in the United Nations System as symbolized by the adoption of UNESCO' recommendation on ethics of neurotechnology (Chiappone and Morrow, 2025; UNESCO, 2025; Giulia, 2025, also see Table 2). The current paper outlines representative examples highlighted in bold in Figure 1, primarily from the perspectives of regulation and international standard-setting activities.

	Organization/Project	Title of Publication	Publication Year	Publication URL
15	OECD Committee for Scientific and Technological Policy	Recommendation of the Council on Responsible Innovation in Neurotechnology	2019	https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0457
16	U.S. ARMY Combat Capabilities Development Command Chemical Biological Center	Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD	2019	https://www.mysterywire.com/wp-content/uploads/sites/106/2019/12/Cyborg-Soldier-2050-CBC-TR-1599.pdf
17	BRAIN Initiative's Multi-Council Working Group	The brain initiative and Neuroethics: Enabling and enhancing neuroscience advances for society.	2019	https://braininitiative.nih.gov/sites/default/files/images/bns_roadmap_11_october_2019_sent_to_acd_for_oct_2019_revised_10282019_508c.pdf
18	IEEE Standards Association	Standard roadmap. Neurotechnologies for brain-machine interfacing.	2020	https://standards.ieee.org/wp-content/uploads/import/documents/presentations/ieee-neurotech-for-bmi-standards-roadmap.pdf
19	BNCI Horizon 2020	The future in brain/neural-computer interaction.	2020	https://openlib.tugraz.at/download.php?id=56194931c6b87&location=browse
20	International Bioethics Committee of UNESCO	Report of the International Bioethics Committee of UNESCO on the ethical issues of neurotechnology.	2021	https://unesdoc.unesco.org/ark:/48223/pf0000378724
21	U.S. FDA Center for Devices and Radiological Health	Implanted Brain-Computer Interface (BCI) Devices for Patients with Non-clinical Testing and Clinical Considerations Guidance for Industry and Food and Drug Administration Staff	2021	https://www.fda.gov/media/120362/download
22	Committee on Bioethics (DH-BIO) Council of Europe	Common Human Rights Challenges Raised by Different Application of Neurotechnologies in the Biomeducal Bield	2021	https://rm.coe.int/report-final-en/1680a429f3
23	Bioethics Advisory Committee Singapore	Neuroscience Research Report	2021	https://file.go.gov.sg/bacneurosciencereport.pdf
24	Neurorights Foundation	International Human Rights Protection Gaps in the Age of Neurotechnology	2022	https://ntc.columbia.edu/wp-content/uploads/2022/05/rightsFoundationPUBLICAnalysis5.6.22.pdf

25	The Law Society	Horizon Report for The Law Society Neurotechnology, law and the legal profession	2022	https://collimateur.uqam.ca/wp-content/uploads/sites/11/2022/09/Neurotechnology-law-and-the-legal-profession-full-report-Aug-2022.pdf
26	Regulatory Horizons Council	Neurotechnology Regulation	2022	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1121251/RHC_Report_on_Neurotechnology_Regulation.pdf
27	United Nation	Request for inputs on neurotechnology and human rights	2023	https://www.ohchr.org/sites/default/files/documents/hrbodies/hrcouncil/advisorycommittee/neurotechnology/NV-Questionnaire-on-neurotech-EN.pdf
28	United Nation Human Rights Council	Draft report on impact, opportunities and challenges of neurotechnology with regard to the promotion and protection of all human rights (A/HRC/AC/31/CRP.1)	2023	https://www.ohchr.org/sites/default/files/documents/hrbodies/hrcouncil/advisorycommittee/sessions/session31/a-hrc-ac-31-crp-1.docx
29	United Nation Human Rights Council	Impact, opportunities and challenges of neurotechnology with regard to the promotion and protection of all human rights	2024	https://digitallibrary.un.org/record/4060417?v=pdf
30	UNICEF Innocenti	Neurotechnology and Children's Rights — Preparing for the Future	2024	https://www.unicef.org/innocenti/innocenti/innocenti/media/11426/file/UNICEF-Innocenti-Neurotech-Childrens-rights-Report-2025.pdf
31	OECD	Neurotechnology Toolkit	2024	https://www.oecd.org/content/dam/oecd/en/topics/policy-sub-issues/emerging-technologies/neurotech-toolkit.pdf
32	GAO	Resolution on principles regarding the processing of personal information in neuroscience and neurotechnology	2024	https://globalprivacyassembly.com/wp-content/uploads/2024/11/Resolution-on-Neurotechnologies.pdf
33	United Nation Human Rights Council	Foundations and principles for the regulation of neurotechnologies and the processing of neurodata from the perspective of the right to privacy	2025	https://docs.un.org/en/A/HRC/58/58
34	UNICEF	Neurotechnology and Children's Rights — Preparing for the Future	2025	https://www.unicef.org/innocenti/innocenti/innocenti/media/11426/file/UNICEF-Innocenti-Neurotech-Childrens-rights-Report-2025.pdf
35	WHO	Landscape analysis of the opportunities and challenges for neurotechnology in global health	2025	https://iris.who.int/handle/10665/381761
36	BRAINMIND	Investor Roundtable Ethical Neuro-Innovation	2025	https://static1.squarespace.com/static/5c983b62348cd93020a6791c/t/686fe04f7bbc5e7002db66cb/1752162386334/BrainMind+Investor+Roundtable+Report.pdf
37	ISO IEC JTC1 SC43	ISO/IEC 8663:2025 Information technology – Brain-computer interfaces – Vocabulary.	2025	https://webstore.iec.ch/en/publication/83033
38	ISO IEC JTC1 SC43	ISO/IEC Technical Report 27599 Information technology – Brain-computer interfaces – Use cases.	2025	https://webstore.iec.ch/en/publication/83014
39	INTERPOL-UNODC Neurotechnology assessment	Background Paper Neurotechnology Law Enforcement and Criminal Justice	2025	https://www.unodc.org/documents/justice-and-prison-reform/technology/UNODC_INTERPOL_Background_Paper_Neurotechnology_Law_Enforcement_and_Criminal_Justice.pdf

40	UNIDIR	Neurotechnology in the Military Domain: A Primer	2025	https://unidir.org/wp-content/uploads/2025/11/UNIDIR_Neurotechnology_Military-Domain_A-Primer.pdf
41	UNESCO	Recommendation on the Ethics of Neurotechnology	2025	unesdoc.unesco.org/ark:/48223/pf0000394861

Table 2
Examples of Policy Reports, Consultation Papers, and Recommendations Relevant to Neurotechnology Regulation Following the 2019 OECD Recommendation (Accessed December 10, 2025)
Note. Serial numbers are derived from Table 1, and part of this list was updated from Table 1 of Fukushi (2024).

3.1. Standard Roadmap published by IEEE Standards Association

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest professional organization for electrical and electronics engineering, headquartered in the US. The IEEE Standards Association usually develops forum standards for industrial technology and influences de jure standardization activities, including International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). This report, published by the IEEE Standards Industry Connections Group on Neurotechnologies for Brain-Machine Interfacing (established in 2017, outlined existing and developing standards related to BCI technologies, compiled recommendations on standardization priorities, and presented a roadmap to develop the standard. The following excerpts highlight key recommendations.

a) Promote better education about the positive effects of standardization.

b) Efforts should be invested on educating the community on how standards are developed.

c) Safety, security and privacy appear as top priorities for standardization.

d) There is a clear lack of standards and agreed practices for the terminology used to specify BMI systems, as well as for assessing performance and benchmarking in relevant working conditions.

e) Existing trends of to improve scientific reproducibility and open science can be leveraged to establish and consolidate standards for data sharing and reporting on neurotechnology developments.

f) The community should consider the possibility of defining complementary standards that scale-up from consumer to clinical applications.

g) It would be important to encourage the implication of BMI researchers in the development of standards and regulations of these complementary technologies.

h) It is important to envision flexible and consistent governance mechanisms ranging from community-agreed good practices, soft law, standards, and regulation. This may be achieved through implementation of strategies such as regulatory sandboxes and regular update of community guidelines and standards.

i) BMI-specific standards should be aligned with emerging frameworks to address ethical, legal, and societal implications of emerging technologies.

Prior to this report's publication, IEEE had initiated activities on two technical standards (IEEE Standards Association P2731 https://standards.ieee.org/

ieee/2731/7383/ and P2794 https://sagroups.ieee.org/2794/). In 2022, the establishment of a new working group to consider international standards for the responsible use and development of neurotechnologies was approved. This group commenced activities in 2023 as P7700: Recommended Practice for the Responsible Design and Development of Neurotechnologies (see IEEE Standard Association P770 https://standards.ieee.org/ieee/7700/11038/). As of January 2026, none of the groups have published documents as international standards, but P7700 at least progresses with the creation and publication of a Recommended Practice.

3.2. Technical Reports by ISO/IEC JTC 1/SC 43 Brain-computer interface

ISO, which develops international standards for industrial technology in general, and IEC, which develops international standards for electrical and electronic technology, established the Joint Technical Committee 1 (JTC1) in 1987 as an organization for standardization in the field of information and communication technology. Within JTC1, SC43 Brain-Computer Interface was established in 2022 as a subcommittee to consider international standards for technical elements related to brain-computer interfaces in the ICT field (see ISO/IEC JTC 1/SC 43 in the ISO website: https://www.iso.org/committee/9082407.html). The Standardization Administration of China serves as the Secretariat for JTC1 for the first time. As of January 2025, there are 10 P-members with voting rights, including Japan, the US, and the UK. Among the 10 O-members who can participate in meetings but do not have voting rights are Argentina and Brazil from the Latin American region. This subcommittee aims to standardize technical aspects of BCI standards related to the information and communications field, excluding items concerning the implantation of industrial products into the human body and medical devices. As of December 2025, a report of defining relevant technical terms (ISO/IEC JTC 1/SC 43, 2025a) and a technical report on use cases (ISO/IEC JTC 1/SC 43, 2025b) have been published. The effort continues on developing standards and study reports concerning data formats and safety. Currently 23 groups from ISO, IEC, and JTC1 register as liaisons with SC43 (https://www.iec.ch/dyn/www/f?p=103:29:409126477704494:::FSP_ORG_ID,FSP_LANG_ID:28794,25#4) including IEC TC62 (covering medical devices), ISO/IEC JTC 1/SC 41 (addressing the Internet of Things and digital twins), and ISO/IEC JTC 1/SC 42 (focused on artificial intelligence), highlighting the diversity of foundational technology domains encompassed by BCI and the multitude of technical elements requiring coordination. Furthermore, a working group was established within SC 43 to examine ethical and societal concerns related to BCI (specifically its information and communication technology elements) and procedures are underway to compile a technical report (https://www.iec.ch/dyn/www/f?p=103:262:409126477704494:::FSP_ORG_ID,FSP_LANG_ID:28794,25).

3.1.1. Neurotechnology Regulation published by Regulatory Horizons Council (UK)

The Regulatory Horizons Council is an independent expert body established based on the UK government's white paper "Regulation for the Fourth Industrial Revolution" (Department for Business & Trade, Department for Business, Energy &

Industrial Strategy, 2019), which examined regulatory reform approaches anticipating the development of advanced technologies. The report named "Neurotechnology Regulation", commissioned by the UK Cabinet, conducted interviews to gather evidence for recommendations on regulatory reforms to promote the rapid and safe development of neurotechnology. It compiled 14 specific recommendations for the regulation and future governance of neurotechnology, including concrete actions and responsible entities such as Medicines & Healthcare Products Regulatory Agency (MHRA) and multiple government departments (Regulatory Horizons Council, 2022).

a) The MHRA should build an enhanced culture of dialogue and early engagement between regulators and innovators.

b) The MHRA should supplement existing guidance on medical device regulation to incorporate specific neurotechnology challenges, explaining in more detail how the existing regulatory framework should be applied to these devices.

c) The MHRA should establish a dedicated sub-group of neurotechnology specialists, to advise on future regulatory adaptation for neurotechnologies.

d) The Department of Health and Social Care (DHSC) should 1) increase funding to the MHRA to sufficiently expand its capacity in neurotechnology device regulation and 2) consider options for increasing the capacity of Approved Bodies to deal with approval demands for neurotechnology devices.

e) The MHRA should consider options for facilitating generation and presentation of clinical evidence and avoiding unnecessary repetition of clinical trials to avoid negatively impacting innovation.

f) The MHRA, Approved Bodies and the NHS should work together to establish a sandbox programme for neurotechnology devices in the UK.

g) All brain modulation devices (invasive and non-invasive) should be regulated under the medical devices framework, irrespective of the purpose for which they are marketed, as proposed by the MHRA. This recommendation should also extend to devices that modulate all neural tissue, and not just the brain.

h) Non-invasive devices that only record neural information (i.e., neurorecording wearables) for non-medical purposes should not be regulated by the MHRA but should be compliant with general consumer protection, security, product safety, privacy and sectoral regulations, according to their use cases

i) The Information Commissioner's Office (ICO) should clarify how the data protection framework would be applied to neurodata. The Council would like ICO's work on neurodata regulation to lead to the publication of guidance, drafted in collaboration with the neurotechnology community.

j) In reforming the UK Data Protection Framework, the Department for Culture, Media and Sport (DCMS) should (1) consider creating a new special category for neurodata to ensure their processing is limited under Article 9 of the GDPR and (2) assess whether existing protections are proportionate to the risks posed by different kinds of neurodata.

k) DHSC should consider adopting policies to ensure that neurotechnologies are available to a wide patient base regardless of their personal characteristics.

l) As part of its plans to amend the UK Medical Devices Regulations to clarify and strengthen the requirement for manufacturers to implement a post-market surveillance and vigilance system, the MHRA should consider requiring manufacturers to present a plan describing how they intend to manage long-term implants installed in patients, as part of their submission to Approved Bodies.

m) HMG should ensure that senior accountability is set out to drive forward and coordinate thinking on neurotechnology regulation across government to enable its transformative potential by addressing existing leadership gaps and avoiding the risks of regulation that is disproportionate or fragmented. As part of this, the establishment of a cross-governmental network of regulators and government departments, including (but not limited to) the MHRA, ICO, Office for Product Safety and Standards (OPSS), DHSC, DCMS, the Department for Business, Energy and Industrial Strategy (BEIS) and the Ministry of Defence (MoD), allied to wide-ranging expertise from industry, academia, patient/user perspectives and medicine, could be considered.

n) HMG should play an active role in international initiatives on neurotechnology and proactively collaborate with other countries to develop an international governance framework that takes account of UK values in the future development of neurotechnology.

In response to these recommendations, the Minister for Science, Research and Innovation (DSIT) and the Minister of State for Health and Secondary Care (DHSC) published a response report in 2024 outlining whether countermeasures would be implemented, their policy direction, and rationale, and began concrete actions. As part of this effort, the National Consortium for Neurotechnology Regulation was formed in 2024, led by Newcastle University, to conduct preliminary studies (https://gtr.ukri.org/projects?ref=10114253). Building on these findings, in 2025, with support from the Advanced Research and Innovation Agency (ARIA), Newcastle University and the Medicines and Healthcare products Regulatory Agency (MHRA) jointly launched a project to consolidate and review existing neurotechnology regulations and develop new regulatory guidance for the UK (https://www.ncl.ac.uk/press/articles/latest/2025/11/regulationofneurotechnologies/). While the US FDA has led the development of regulations for neurotechnology medical devices, attention must be paid to future developments in the UK —a country that has raised ethical questions concerning various biotechnology fields since the 20th century and influenced regulatory discussions— regarding what kind of neurotechnology regulatory strategy will be established.

Conclusion

As discussed in the previous section, following the OECD's recommendations, activities related to international rulemaking have intensified, exemplified by the development of recommendations and reports by agencies within the United Nations System. Furthermore, as activities closely tied to industry, discussions on international standards, as mentioned in the previous chapter, have become more active. These trends clearly demonstrate that the importance of international rulemaking is widely recognized among OECD member countries, anticipating the intensifying

competition in neurotechnology development and its widespread adoption. At the national level, an example exists where multiple public agencies collaborate to develop regulatory frameworks for neurotechnology as both medical and non-medical devices within their own countries, such as in the UK. As other authors in this book chapters introduced, Latin American countries are advancing discussions on legal frameworks that consider neurotechnology's impact on human rights. In contrast to such nations, Japan has seen active neurotechnology R&D in academia, yet progress on a national-level response to the OECD recommendations has been slow (Fukushi, 2024). However, following the adoption of the UNESCO Recommendation (UNESCO, 2025, also see https://www.unesco.org/en/articles/ethics-neurotechnology-unesco-adopts-first-global-standard-cutting-edge-technology), the importance of regulating and governing neurotechnology is increasingly being recognized within Japanese academia and government ministries. Over the next few years, rule-making efforts by various international organizations are expected to intensify further, and it is hoped that national-level discussions in Japan will advance in line with this trend.

Acknowledgement

This work is supported by JST RISTEX RInCA JPMJRS25J2 and JST Moonshot JPMJMS2012.

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— 2 —

Corporate neurotechnology and the limits of the business and human rights framework: toward precautionary governance

FELIPE PAREDES[1]

Introduction

In recent years, neurotechnology has emerged as one of the most striking fields of innovation at the intersection of science, technology, and society. Devices such as brain–computer interfaces, portable electroencephalography systems, and neurostimulation tools—initially developed for clinical and research purposes—have been incorporated into mass consumer markets, including wellness, education, workplace productivity, and entertainment. This process has been driven largely by private companies, which now play a central role in the design, commercialization, and governance of these technologies.

The expansion of corporate neurotechnology poses unprecedented challenges for protecting human rights. Neurotechnology can already infer and even modulate mental processes, thereby placing fundamental rights such as privacy, autonomy, freedom of thought, and equality under strain. In particular, the collection and processing of neural data—one of the most sensitive forms of personal information—as well as the deployment of technologies capable of influencing cognition and behavior, open a range of risks that traditional legal frameworks were not designed to anticipate or adequately regulate.

Much of the recent academic debate has responded to these challenges by proposing the creation of new rights. On the one hand, so-called "neurorights" have been advanced (Yuste et al., 2021) to protect specific dimensions of the human mind from neurotechnological interventions. On the other hand, scholars have proposed recog-

[1] Associate Professor at Faculty of Law of Universidad Austral de Chile. email: felipe.paredes@uach.cl

nizing the notion of "cognitive rights" as an alternative avenue (Farahany, 2023, p. 212). However, the recognition of new rights—beyond a legal debate that remains unresolved—does not exhaust the problem of neurotechnology governance, particularly when the main actors are private corporations operating in global, highly dynamic markets. In this respect, the approach advanced here does not preclude the creation of new rights; rather, it seeks a complementary strategy that uses existing legal frameworks.

Within this context, the business and human rights framework, particularly the United Nations Guiding Principles on Business and Human Rights (UNGPs), constitutes a key analytical tool for assessing corporate responsibility regarding neurotechnological risks. The UNGPs provide a widely accepted normative architecture based on three pillars: the State duty to protect, the corporate responsibility to respect human rights, and access to remedy. They have proven effective in areas such as supply chains, environmental protection, and labor rights. Nevertheless, this article claims that corporate neurotechnology exposes structural limitations within this framework.

The article discusses that, although they remain normatively relevant, the UNGPs are insufficient to address the novel forms of harm generated by neurotechnology. These risks are emergent, cumulative, diffuse, and epistemically uncertain: their effects are not always foreseeable *ex ante, nor are they always manifest immediately, and they may also* affect rights that are still in the process of legal recognition. These features challenge the assumptions underpinning human rights due diligence –the main UNGPs tool- as well as the classical criteria for identifying, preventing, and mitigating corporate impacts.

To address this gap, the article proposes an adjustment to, or a complement of, the UNGPs through a precautionary approach inspired by environmental governance. Such an approach would make it possible to anticipate and mitigate systemic, cumulative, and uncertain harms, even in the absence of full scientific certainty. The objective is not to replace the UNGPs, but to strengthen them by incorporating *ex ante* assessment criteria, shared responsibility, and active precaution, and to adapt the framework to a technological context that is profoundly transforming the relationship among markets, power, and human beings.

The article is structured as follows. First, it describes the rise of corporate neurotechnology and the asymmetries that characterize its development. Second, it identifies the main human rights risks associated with these technologies. Third, it examines the gaps in international human rights law and the role of the UNGPs as a framework for corporate governance. It then develops a systematic critique of the limits of this framework in addressing emerging harms and rights that are still in the pipeline. Finally, it outlines directions for an adaptive and precautionary governance of neurotechnology that is compatible with the effective protection of human rights.

1. Corporate neurotechnology: types and characteristics of human rights risks

The expansion of neurotechnology into non-clinical domains has been driven by rapid commercialization led primarily by private actors. Devices such as non-

invasive brain–computer interfaces, portable electroencephalography systems, and neurostimulation tools—originally developed for medical or research purposes—are increasingly being incorporated into consumer markets related to wellness, workplace productivity, education, and entertainment (Ienca & Andorno, 2017). In this context, companies such as Emotiv, Neuralink, and a wide range of startups now play a central role in the design, deployment, and governance of these technologies.

Unlike traditional clinical settings, consumer neurotechnology operates within a fragmented and, in many cases, insufficient regulatory environment. The accelerated pace of technological innovation, combined with economic incentives favoring rapid adoption and product scaling, often outstrips the capacity of existing legal frameworks to anticipate and manage associated risks (Ienca et al., 2022). This situation is further exacerbated by profound information asymmetries between companies and users (Guihot & McNaught, 2021). Against this backdrop, corporate neurotechnology poses a particularly challenging risk to the protection of human rights. Three areas are especially salient: mental privacy, cognitive liberty, and equality and non-discrimination.

First, regarding mental privacy, neural data—the electronic register of brain activity—can reveal highly sensitive information about individuals, including emotional states, cognitive patterns, behavioral predispositions, and even neurological conditions (Magee et al., 2024). Unlike other categories of personal data, neural data are characterized by their extreme intimacy, their largely involuntary production, and the difficulty individuals face in fully understanding their scope and potential uses (Pauzauskie et al., 2025).

In the consumer neurotechnology domain, many devices collect and process neural data with limited transparency about how consumer's data is stored, reused, or potentially shared with third parties (Farahany, 2023; Ienca et al., 2022). This opacity creates risks that extend beyond mere violations of informational privacy, giving rise to what have been described as epistemic harm (Risse, 2021); by enabling inferences, classifications, or mental profiles, these technologies erode autonomy by exposing individuals' pre-conscious states to external monitoring before they can be consciously processed. In this setting, traditional mechanisms of informed consent and individual control are profoundly weakened, to the point of becoming ineffective (Solove, 2024).

This opacity has been empirically confirmed by recent studies on corporate practices in consumer neurotechnology. An analysis of the privacy policies of thirty companies in the sector by Genser, Damianos, and Yuste (2024, p. 41) revealed that 96.67% retain broad access to users' neural data without substantive or legally enforceable limits. Even when restrictions are mentioned, they are often vague and defined unilaterally by the companies. Such practices are irreconcilable with the principles of transparency, data minimization, and storage limitation that underpin international data protection standards, further exacerbating risks to mental privacy in non-clinical contexts.

Second, significant risks arise regarding cognitive liberty, understood as the right of individuals to govern their own mental processes and to be protected against unwanted or coercive interference. This principle extends classical notions of autonomy and mental integrity into the neural domain. The concept has gained substantial

traction, particularly concerning interventions in mental states through cutting-edge neuro-pharmaceuticals or advanced neurotechnological devices (Bublitz, 2026). In this context, the commercial deployment of neurostimulation devices introduces novel risks that challenge existing protective frameworks, especially when utilized to influence, modulate, or optimize users' attention, mood, or cognitive performance (Farahany, 2023)."

Admittedly, full external mental control remains hypothetical, as there is currently no evidence of devices capable of direct 'mind control' over another individual. However, there is clear evidence of technologies that can induce specific neural stimuli to influence actions and decisions in particular contexts. Notably, non-invasive neuromodulation techniques such as repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS) have demonstrated measurable effects on cognitive and behavioral functions. These effects are particularly evident when targeting cortical areas associated with executive control and impulsivity (Moro et al., 2023; Casula et al., 2023)."

While these effects are typically modest and context-dependent, they demonstrate that even non-invasive interventions can modulate decision-making processes and cognitive states. Precisely because of their subtle, gradual, and socially normalized nature, such interferences are difficult to categorize as violations of fundamental rights. In most cases, there is no clearly defined 'harmful event' or immediate perception of injury by the individual. This undetectability poses a direct challenge to traditional legal criteria regarding harm, consent, and liability (Ligthart, 2025).

Third, neurotechnologies raise critical concerns regarding equality and non-discrimination. Algorithmic systems processing neural data can amplify biases embedded in training datasets, leading to discriminatory outcomes in employment, education, and healthcare (Schleidgen & Wolkenstein, 2022). Furthermore, as these devices are commercialized at scale, access to cognitive enhancement may be restricted by socioeconomic status, deepening existing inequalities and creating new forms of social stratification (Yuste et al., 2017).

Behaviorally intelligent neurotechnologies (B-INT) process neural data to guide user behavior through mental state feedback (Schleidgen, Friedrich & Wolkenstein, 2022). This dynamic illustrates how algorithmic risks emerge at both the production and utilization stages. At the production level, technical failures or biased training data can generate erroneous information, prompting misguided personal decisions. However, even when the data is accurate, bias often stems from its teleological use. This is exemplified by a hypothetical scene Mario: a system called 'RateMe' that classifies individuals originally based on commercial interests while disregarding justice. When such systems are used indiscriminately by employers, banks, or law enforcement, they generate exclusion and restricted opportunities. Thus, even when functioning as intended, these technologies can facilitate algorithmic bias, epistemic harm, and cognitive injustice.

Taken together, these considerations suggest that harms associated with neurotechnology do not always manifest as isolated or easily identifiable individual rights violations, but rather as collective, cumulative, and progressive effects that unfold over time and across multiple contexts of use. The sustained introduction of neurotechnological systems into domains such as work, education, consumption, or mental

health may gradually alter the conditions under which individuals make decisions, compete for opportunities, or are evaluated, without necessarily resulting in a single harmful act attributable to a specific company or device. These impacts tend to manifest systematically, for example, through the normalization of technologically reinforced cognitive standards, the production of new forms of stratification based on neuro-optimized capacities, or the generation of systemic biases resulting from the repeated use of neural data in classification and prediction processes.

From a legal perspective, this type of harm poses substantive challenges that exceed traditional frameworks of responsibility attribution, which are centered on bilateral relationships, discrete events, and individualized harms. Neurotechnological effects, by contrast, may emerge from the aggregated interaction of multiple ostensibly neutral corporate decisions, whose impacts become visible only at a collective level or over the long term. This complicates both the evidentiary demonstration of harm and the identification of a direct causal link, while also calling into question the sufficiency of classical mechanisms of individual consent as an effective safeguard. Consequently, the governance of neurotechnology requires approaches capable of capturing these systemic and diffuse impacts, incorporating ex ante evaluation criteria, precautionary analysis, and shared responsibilities in order to anticipate and mitigate harms that do not present themselves immediately or individually, but may profoundly affect the conditions under which fundamental rights are exercised.

This risk profile challenges the classical assumptions underpinning business and human rights governance frameworks, particularly those based on the ex ante identification of foreseeable risks, clear causal relationships, and fully established rights. In this sense, corporate neurotechnology constitutes a particularly demanding terrain for assessing the adequacy and limits of the United Nations Guiding Principles on Business and Human Rights as a framework for preventing and managing harm.

2. The United Nations Guiding Principles in the face of corporate neurotechnology

The United Nations Guiding Principles on Business and Human Rights (UNGPs), adopted by the Human Rights Council in 2011 under the leadership of John Ruggie, currently represent the most widely recognized international framework for governing the human rights impacts of business activities (Assenza, 2025, p. 13). Their significance lies in articulating a dual structure of responsibility: on the one hand, States have a duty to protect human rights from abuse committed by third parties; on the other, business enterprises have a responsibility to respect those rights and to remedy adverse impacts arising from their operations.

The UNGPs are organized around three core pillars:

a) State duty to protect: Governments must adopt policies, legislation, and regulatory mechanisms to prevent, investigate, and sanction human rights abuses by business enterprises, ensuring their effective enforcement.

b) Corporate responsibility to respect: Business enterprises must avoid infringing on human rights and must address adverse impacts with which they are involved, regardless of the State's ability or willingness to fulfill its protective role.

c) Access to remedy: Individuals affected by business-related human rights violations must have access to effective judicial and non-judicial mechanisms to obtain redress.

When applied to the field of neurotechnology, these principles appear, at first sight, to offer a conceptual framework for organizing responsibilities and ensuring standards of corporate conduct. Central among these standards is the requirement that business enterprises avoid, prevent, and mitigate adverse human rights impacts through the implementation of human rights due diligence (HRDD). HRDD entails the systematic identification, prevention, mitigation, and accountability for potential adverse impacts arising from business operations (Bonnitcha & McCorquodale, 2017, p. 900). In the neurotechnology context, this would include, *inter alia*, oversight of neural data collection, assessment of the risk of cognitive interference, and prevention of algorithmic discrimination.

At first glance, the UNGPs appear well-suited to address the challenges posed by corporate neurotechnology. They establish a universal standard of corporate responsibility applicable to multinational corporations and startups alike; they promote a preventive approach centered on anticipating impacts before they materialize; and they recognize the complementarity between State regulation and corporate responsibility, allowing the framework to function in fragmented regulatory environments such as those characteristics of neurotechnology markets.

However, when the assumptions underlying the UNGPs are contrasted with the risk profile of corporate neurotechnology outlined in the previous section, significant tensions emerge. The UNGPs were largely designed to respond to contexts in which business-related human rights risks are known or at least reasonably foreseeable. Their normative architecture presupposes the possibility of identifying potential negative impacts *ex ante*, establishing relatively clear causal links between corporate decisions and concrete harms, and designing preventive or mitigating measures grounded in sufficient technical or scientific consensus. This model has proven particularly effective in areas such as supply chains, environmental harm, occupational safety, or impacts on the traditional ways of life of local communities, where risk patterns are well documented and the rights at stake—life, health, physical integrity, and social and economic inclusion—are firmly entrenched in international law.

Consistent with these assumptions, human rights due diligence is structured as a process of impact identification, assessment, and management that, while dynamic, rests on the ability to anticipate relatively well-defined risk scenarios and to attribute responsibility to identifiable business actors. The UNGPs framework also assumes that the rights potentially affected enjoy a sufficient degree of normative and conceptual recognition, enabling an assessment of when corporate conduct constitutes a violation and which standards should apply to prevent or remedy it. For this reason, the focus in this field has not been on creating new rights but on enforcing existing ones. Indeed, scholarly literature often emphasizes the broad international support for the UNGPs, grounded in a global, pragmatic, and generic consensus among the private sector, governments, civil society organizations, and the United Nations regarding the role of business in the human rights agenda (Shivji, 2025, p. 409).

Corporate neurotechnology profoundly challenges these assumptions. As will be explained in greater detail in the following section, many of the risks associated

with the collection and processing of neural data are emergent, uncertain, and context-dependent, making them difficult to anticipate in classical terms. Moreover, impacts often manifest in diffuse, cumulative, or systemic ways, complicating their attribution to a specific corporate decision or to a single product or service. In addition, several of the legal interests potentially affected—such as mental privacy, cognitive liberty, and psychological continuity—are still in the process of recognition and conceptual development, with fully stabilized legal standards lacking. Finally, scientific consensus regarding the long-term effects of many neurotechnological applications remains limited or under development, constraining the ability to ground mitigation measures exclusively in consolidated evidence. This mismatch between the conceptual design of the UNGPs and the realities of neurotechnological risks lies at the core of the tension examined in the next section.

In this context, applying the UNGPs without adjustment risks rendering the framework overly formalistic or insufficient, insofar as it demands levels of foreseeability, attribution, and certainty that are not always available in the neurotechnology domain. This does not imply the irrelevance of the framework, but rather the need to reinterpret and complement it by incorporating approaches more sensitive to uncertainty, collective harm, and the protection of rights still under development, as well as precautionary criteria that enable action in the face of plausible risks even where they are not yet fully substantiated. In sum, the UNGPs provide a valuable structural framework, but their application to neurotechnology requires critical scrutiny and adaptation, given the novel, diffuse, and evolving nature of the risks associated with business activity in this field.

3. Structural limits of the guiding principles in the context of corporate neurotechnology

As discussed earlier, corporate neurotechnology poses a significant challenge to the UNGPs, given its combination of emerging risks, cumulative impacts, and rights that are still in formation. Although the UNGPs represent the most widely accepted international framework for guiding corporate conduct and State regulation, their design—originally conceived to address labour, environmental, or supply-chain-related risks—reveals structural limitations when applied to technologies that interact directly with the human mind.

First, the UNGPs operate as a generic normative framework. This feature grants them flexibility and enables adaptation across diverse business contexts, but it also entails a lack of operational precision when confronting risks that remain poorly understood, such as neurotechnological risks (Bernaz, 2017; Del Grossi, 2025). HRDD, the central mechanism of the UNGPs, requires business enterprises to identify and mitigate human rights impacts, yet it does not provide sufficiently operational criteria for assessing subtle, emergent, or difficult-to-quantify risks. For example, the effects of an implantable brain–computer interface on attention, memory, or decision-making are difficult to detect and do not always manifest immediately. This ambiguity limits companies' ability to apply HRDD effectively and renders the UNGPs more aspirational than operational in neurotechnological contexts.

Moreover, neurotechnology introduces novel typologies of harm that challenge the traditional assumptions of foreseeability and attribution embedded in the UNGPs. Emergent harms—those that become observable only after sustained or large-scale use of devices—include subtle alterations in attention, memory, or emotional states (Farahany, 2023). These are compounded by cumulative harms resulting from long–exposure to brain–computer interfaces or neurostimulation systems, as well as subtle harms in which cognitive or affective effects occur without direct intent or user awareness (Ienca et al., 2022). Such forms of harm are not only difficult to anticipate but also strain traditional mechanisms of responsibility and mitigation designed for more tangible and measurable impacts (Garden et al., 2019, p. 19).

HRDD, conceived primarily to anticipate and manage known risks—although some authors, such as Rogge (2022), argue that it can also serve as a useful tool for addressing uncertainty—faces significant epistemic obstacles in the neurotechnology domain. Scientific evidence regarding the cognitive and affective effects of neural devices remains partial and contested, complicating the identification of known impacts and, consequently, the implementation of effective preventive measures. Causal attribution is likewise problematic, as cognitive or affective changes may depend on multiple factors external to the device, making it difficult to establish direct corporate responsibility. Another pitfall relates to the fact that neurotechnology can cause collective or systemic impacts, affecting entire groups rather than isolated individuals and thus hinder the application of the remedial and oversight mechanisms envisioned by the UNGPs (Yuste et al., 2017; Ienca et al., 2022).

Finally, neurotechnology interacts with human rights that are still emerging or contested, such as mental privacy, cognitive liberty, and psychological integrity. Whereas the UNGPs presuppose the existence of a fully recognized legal framework, these emerging rights lack clear legal definitions and normative consensus, generating grey areas that complicate both responsible corporate action and effective State oversight (Ienca & Andorno, 2017; Farahany, 2023). This situation underscores the fact that, although structurally valuable, the UNGPs do not, on their own, provide the tools necessary to ensure the effective protection of the human mind amid the expansion of corporate neurotechnology.

Taken together, these elements demonstrate that corporate neurotechnology constitutes a borderline case for the UNGPs. The abstract nature of the principles, the emergence of cumulative and emergent harms, the epistemic obstacles to due diligence, and the existence of rights still under construction all point to the need for adaptive and precautionary approaches, to achieve effective governance of neurotechnology that goes beyond mere articulation of good intentions.

4. Toward an adaptive governance of neurotechnology

The precautionary principle provides a useful conceptual reference for addressing this challenge. Originating in environmental law, it primarily guides action in the face of potentially serious or irreversible risks, even when conclusive scientific evidence on the magnitude or likelihood of harm is lacking. The principle recognizes that the absence of certainty should not preclude preventive action and calls for measures proportionate to the severity of the risk, prioritizing protection against

irreversible consequences. Traditionally applied in contexts such as pollution control or biodiversity loss, the precautionary principle has steered regulation toward ex ante assessment in situations of high epistemic uncertainty, rather than reliance solely on ex post proof of harm (de Sadeleer, 2006).

Operationally, the precautionary principle functions through a reversal of the burden of proof and the requirement of proactive risk-mapping. Unlike traditional risk management—which necessitates empirical evidence of causality to trigger intervention—the precautionary approach is activated by the plausibility of harm. It mandates that when an activity poses a threat of serious or irreversible damage to human cognitive integrity or mental privacy, the absence of full scientific certainty shall not be used as a reason for postponing cost-effective measures. Consequently, it shifts the focus from merely managing 'known-impacts' to implementing pre-emptive safeguards, such as 'safety-by-design' protocols and rigorous transparency requirements, even before a clear causal link is established (de Sadeleer, 2020)."

When applied to corporate neurotechnology, the precautionary principle entails adopting governance instruments that anticipate and mitigate systemic harms before they materialize, consistent with the view that the UNGPs require a precautionary adjustment to address emergent, cumulative, and epistemically uncertain risks. Such measures may include:

a) Ex Ante Cognitive Impact Assessments: Similar to the well-established environmental impact assessments that gauge the potential ecological consequences of a project before it commences, there is a pressing need for companies to conduct thorough preliminary studies evaluating the effects of their technological devices on critical cognitive functions. This includes assessing impacts on attention span, memory retention, emotional states, and decision-making processes. Such assessments should be mandated as a prerequisite for market entry to ensure that any potential cognitive risks are identified and mitigated before products reach consumers.

b) Independent Neuroethical Audits: To foster a comprehensive understanding of the ethical implications of neural technologies, interdisciplinary committees should be formed. These committees should consist of experts in neuroscience, ethics, and law who would conduct regular evaluations of algorithms and devices. This process should not depend on conclusive evidence of harm; rather, it should proactively assess any potential risks associated with these technologies. This systematic approach aims to ensure that ethical considerations are consistently integrated into the development and deployment of neurotechnology.

c) International Standards for Neural Data: The management of neural data, which encompasses the collection, storage, and application of brain signals, demands robust global standards to ensure ethical practices across borders. These standards should establish minimum guidelines that prevent the use of neural data in uncertain or scientifically unverified ways, aligning with a precautionary principle. Such regulations must protect individuals from potential exploitation or misuse of their neural information.

d) Enhanced Dynamic Consent: In an era where the usage of neural data can evolve rapidly, the concept of consent should likewise advance. Individuals should be granted enhanced dynamic consent, which ensures their consent is automatically updated in response to changes in how their neural data is used. This proactive

approach offers a robust layer of protection for users, shielding them from potential risks associated with emerging or ambiguous applications of their neural information.

This approach acknowledges that neurotechnological harms do not always manifest as isolated violations of individual rights, but rather as collective, cumulative effects that gradually reshape the conditions under which fundamental rights are exercised. Integrating the precautionary principle into the corporate governance of neurotechnology enables anticipation of diffuse, systemic impacts and provides a more appropriate response than traditional HRDD alone. Accordingly, corporate neurotechnology constitutes a domain in which adaptive governance must go beyond the UNGPs, incorporating precaution, ex ante evaluation, and shared responsibility in order to ensure the effective protection of mental privacy, cognitive liberty, and equality in increasingly neurotechnologized societies.

Conclusions

The study highlights that while the UN Guiding Principles on Business and Human Rights provide a foundational framework for corporate responsibility, their application to neurotechnology reveals structural limitations. Emerging, diffuse, and cumulative risks, coupled with rights in formation such as mental privacy and cognitive liberty, challenge traditional models of due diligence.

To address these gaps, a governance approach that integrates precautionary and adaptive principles is necessary. Evaluations of cognitive impact, independent neuroethical audits, international standards for neural data, and dynamic consent mechanisms can complement existing UNGPs, ensuring proactive protection of human rights in neurotechnological contexts.

Ultimately, the protection of human dignity in the age of neurotechnology requires moving beyond formalistic compliance, embracing flexible, anticipatory, and collective strategies that respond to uncertain and evolving risks.

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— 3 —

Governing the cognitive economy: economic freedom, power and trust

CAMILA PINTARELLI[1]

Contents: 1. Introduction; 2. The cognitive economy and the limits of traditional regulatory frameworks; 3. Regulating the cognitive economy: freedom to act, economic power, trust, and the constitutional organization of markets; 4. The role of companies in the governance architecture of the cognitive economy: institutional responsibility, trust, and market legitimacy; Conclusion; References.

1. Introduction

Over the past decades, we have observed profound structural transformations in the economic organization of contemporary societies. The industrial economy, grounded in material production and the centrality of physical labor, has been progressively replaced by a digital economy structured around data, connectivity, platforms, and informational flows.

More recently, signs of a new inflection have begun to emerge—one that remains insufficiently delineated from a legal and economic perspective—in which the human mind—its internal processes, cognitive states, and decision-making dynamics—comes to be directly integrated into the logic of economic value creation, organization, and appropriation. In this shift, dimensions traditionally treated as external to productive activity are relocated within the individual.

It is within this context that we propose the notion of a cognitive economy, understood as the set of economic practices that systematically and technologically mediate human cognition as a relevant element of economic activity. More specifically, we refer to practices in which inferences about mental states or interventions in cognitive processes come to guide economically significant decisions, such as segmentation, pricing, selection, allocation of opportunities, or the design of choice environments.

[1] Post-Doctorate in Law (University of Coimbra); Member of the Global Future Council on Neurotechnology and of the Global Regulatory Innovation Platform (GRIP), both from World Economic Forum; State Attorney and advocate for the constitutional reform of neurorights in Brazil

Attention, emotion, fatigue, engagement, and decision-making patterns cease to function merely as subjective presuppositions of individual behavior and instead become objects of monitoring, inference, modeling, or modulation through advanced technologies, including neurotechnologies, sophisticated artificial intelligence systems, behavioral biometrics, and adaptive digital environments.

It is a trend that can be traced back to the mid-2010s, with the rise of a techno-social phenomenon commonly referred to as the "quantified self," corresponding to individuals' engagement in actively promoting the tracking of all kinds of biological, physical, behavioral, or even environmental information, reflecting a proactive stance toward the collection of personal data and the ability to act upon it (SWAN, 2013).

One of the most prominent examples of this trend is the practice of monitoring the number of steps taken over the course of a day or during a specific physical activity. This phenomenon has taken on an entirely new scale with the widespread adoption of wearable and portable electronic devices – such as smartphones and smartwatches – through which the potential for quantifying personal information has expanded beyond predominantly external and behavioral data to encompass data sources that, until recently, could only be collected through medical devices, such as electroencephalography (IENCA & MALGIERI, 2022). This shift unquestionably adds new layers of complexity to social life and opens new economic domains for exploration.

Unlike earlier stages of economic development, this transformation does not consist merely in influencing external choices or analyzing observable behavior, but in operating directly on the very processes through which volition is formed, integrating them into the mechanisms that govern market functioning.

The emergence of this economic configuration should not be understood as a future hypothesis or a merely speculative exercise, insofar as its manifestations are already evident in strategic and sensitive sectors such as healthcare and rehabilitation, education, labor, insurance, consumption, advertising, and corporate well-being. In these contexts, economically relevant decisions increasingly rely on inferences about individual mental states, produced continuously, automatically, and often opaquely. This dynamic not only intensifies informational asymmetries but also reconfigures the distribution of power within market relations. It resonates with contemporary analyses of diffuse forms of power, in which influence is exercised less through explicit coercion and more through the silent shaping of the decision spaces available to individuals (SANTOS, 1985).

Against this backdrop, the central question guiding this article becomes unavoidable: are we facing a new economic activity, endowed with its own characteristics and capable of challenging the traditional foundations of market regulation?

The answer to this question is not merely conceptual. It carries direct implications for how freedom of initiative, free competition, and the role of the State in organizing the economic order are to be understood—particularly when one considers that the economic exploitation of core elements of human subjectivity may give rise to new forms of power concentration and to the neutralization of the agents' freedom to act in the market.

From a constitutional standpoint, the issue lies in examining the extent to which the cognitive economy affects the material conditions for exercising the foundational economic freedoms enshrined in Article 170 of the Brazilian Federal Constitution—not only the freedom to undertake economic activity, but also the freedom of economic agents to act in the marketplace—and, consequently, the very integrity of competition.

We argue, in this sense, that the cognitive economy presents qualitatively distinct features when compared to earlier phases of economic activity, precisely because it operates upon the most sensitive dimension of human experience: the internal sphere of cognition, thought, and self-determination.

By doing so, it calls into question core assumptions underlying traditional regulatory models, which were designed to address tangible goods, external information, or observable conduct. When the internal processes of will formation become integrated into mechanisms of value creation, regulation ceases to perform merely its classic function of correcting market failures and instead assumes a structuring role in defining the legitimate conditions under which economic activity may be exercised, in accordance with the constitutional principles of the economic order.

In this context, we reject interpretations that portray regulation as an obstacle to innovation. On the contrary, we understand regulation as normative infrastructure, indispensable to the existence, legitimacy, and sustainability of the cognitive economy—capable of preserving the freedom of economic agents to act, preventing subtle forms of abuse of power, and creating institutional conditions of trust. In the absence of clear boundaries, legal predictability, and verifiable governance mechanisms, the cognitive economy tends to generate deep asymmetries, adverse social reactions, and belated, fragmented regulatory responses, undermining both individual protection and market stability.

It is from these premises that the present article is structured. We begin by examining the cognitive economy and demonstrating why traditional regulatory frameworks prove insufficient to address its specific risks. We then analyze how these shortcomings connect to classic problems of Economic Law, particularly regarding freedom of initiative, free competition, and the abuse of economic power. Finally, we argue that the cognitive economy can only consolidate itself as a viable and constitutionally legitimate economic activity when anchored in regulatory structures capable of protecting the freedom of economic agents to act, containing cognitive asymmetries, and producing institutional trust.

It is within this balance – between economic freedom, regulation, and trust – that the key lies to reconciling technological innovation with the constitutional economic order in the twenty-first century.

2. The cognitive economy and the limits of traditional regulatory frameworks

By asserting that the cognitive economy constitutes a new layer of economic activity, it becomes necessary to delineate its contours with greater precision and, above all, to understand why the legal instruments traditionally employed to regulate digital markets prove insufficient to address its specific risks. The regulatory

challenge does not stem solely from technological novelty, but from the nature of the economic object at stake: mental processes, cognitive states, and the internal dynamics of human subjectivity.

Across multiple economic sectors, practices that concretely illustrate the functioning of the cognitive economy can already be observed.

In the fields of healthcare and rehabilitation, devices and systems capable of monitoring neural patterns, levels of attention, fatigue, or emotional states are being used both for therapeutic purposes and for the continuous assessment of cognitive performance. In education, adaptive digital platforms adjust content and pedagogical methods based on inferences about students' concentration, engagement, or cognitive difficulties. In the workplace, technologies designed to measure productivity, well-being, or occupational risk increasingly incorporate neurophysiological and behavioral metrics, often under the rationale of efficiency and prevention. In consumption and advertising, algorithms are employed to anticipate individual decisions through the analysis of emotions, impulsivity, and risk propensity, reshaping traditional practices of commercial persuasion.

These examples reveal that the cognitive economy already operates as a concrete economic activity, even if it is not always explicitly recognized as such. In all these contexts, economically relevant decisions are increasingly guided by inferences about individual mental states, produced continuously, automatically, and often opaquely. The human mind thus ceases to function merely as a presupposition of economic action and becomes integrated into value-creation processes, redistributing power, risks, and responsibilities within market relations.

The cognitive economy differs from earlier stages of economic development because it is not limited to the collection, processing, or circulation of information external to the individual. Its core lies in the capacity to infer, anticipate, model, or influence mental states through the integration of physiological data, behavioral patterns, engagement metrics, emotional responses, biometric signals, and contextual interactions.

Regulatory risk therefore shifts from the data itself to the cognitive effect produced.

Traditional regulatory frameworks – including those developed for the digital economy – were structured around different assumptions: the protection of tangible goods, the safeguarding of external information, or the regulation of observable conduct. In such models, regulatory risk was primarily associated with informational asymmetries or with violations of privacy understood as an informational sphere. In the context of the cognitive economy, however, these assumptions prove insufficient, as the core of the risk increasingly lies in the systematic production of inferences about mental states and in the redistribution of decisional power within economic relations.

Regulation, in this new scenario, can no longer be confined to the logic of formal consent or data classification. It must evolve toward an effects-based approach, capable of capturing cognitive impacts, structural asymmetries, and risks associated with integrating the human mind into economic processes. This normative progression requires a shift in focus: from the protection of informational objects to the

protection of sensitive human functions; from the analysis of technological means to the evaluation of the effects produced; and from reactive regulatory models to anticipatory regulatory architectures (PINTARELLI & OXLEY, 2025).

Moreover, the cognitive economy intensifies structural asymmetries between economic agents and individuals. We refer to informational asymmetry as inequality in access to relevant information, and to cognitive asymmetry as inequality in the capacity to produce, interpret, and exploit inferences about the very formation of individual will.

While economic agents possess complex predictive models, extensive data infrastructures, and continuous mechanisms of algorithmic learning, individuals remain largely unable to identify which inferences are being generated, with what degree of reliability, and with what effects on their choices. This opacity undermines classical assumptions of consumer rationality and weakens traditional tools for correcting market failures, transforming cognitive asymmetry into a concentrated competitive advantage and a vector for asymmetric redistribution of power.

These asymmetries become even more pronounced in sectors where the cognitive economy manifests with greater intensity. Although such technologies offer significant benefits, their regulation remains fragmented, often dispersed across norms incapable of capturing the specificity of cognitive risks. The result is a landscape of legal uncertainty affecting both individuals and firms.

Considering this scenario, it becomes imperative to recognize that the cognitive economy requires a regulatory approach that is effects-based, technologically neutral, and sensitive to cognitive asymmetries. Rather than asking merely which technology is used, regulation must inquire what type of inference is produced, what impact it has on individual autonomy, and how power and risk are redistributed within the market. Regulation thus emerges not as a barrier to innovation, but as an indispensable condition for the legitimacy and sustainability of this new economic activity.

3. Regulating the cognitive economy: freedom to act, economic power, trust, and the constitutional organization of markets

Analyzing the cognitive economy through the lens of Economic Law requires a careful re-reading of the constitutional foundations of Brazil's economic order, particularly those enshrined in Article 170 of the Federal Constitution.

Although freedom of initiative has traditionally been associated with the prerogative of economic agents to organize, explore, and develop productive activities—assuming risks and seeking returns in the market—a systematic and contemporary reading of the constitutional text reveals that this freedom does not exhaust itself in the supply-side dimension, but also extends to the material conditions under which other economic agents, particularly consumers, are able to act.

From this perspective, freedom of initiative presupposes the existence of minimally intact choice environments, in which economic decisions can be made genuinely, informatively, and without being structurally neutralized by deep asymmetries of power. The cognitive economy directly challenges this presupposition by introducing economic practices capable of operating upon the very internal processes

through which will is formed, displacing the traditional axis of economic regulation from observable conduct to the invisible architecture of decision-making.

Within this framework, the consumer's freedom to act – understood as the effective capacity to form, revise, and execute economic decisions – assumes a central role in legal-economic analysis. It is no longer sufficient to ensure formal alternatives of choice; what must be preserved is the integrity of the cognitive processes that render those choices materially meaningful. When inferences regarding attention, fatigue, impulsiveness, emotional states, or risk propensity are used to continuously and opaquely shape decision environments, formal freedom remains intact, but its substantive content is progressively hollowed out.

It is at this point that the cognitive economy reveals new modalities of exercising economic power.

As we have argued in previous work on the abuse of economic power in the age of neurotechnology (PINTARELLI, 2025), contemporary economic power does not manifest solely through classical practices such as abusive pricing, contractual exclusion, or predatory conduct. It also operates through the neutralization of possibilities for action, reducing the effective space of individual choice without formally eliminating available market alternatives.

In the cognitive economy, such neutralization occurs when economic agents acquire technical, computational, and analytical capacities far superior to those of individuals, enabling them to infer mental states, anticipate emotional reactions, and modulate preferences in a continuous, adaptive, and scarcely perceptible manner. The resulting asymmetry is not merely informational, but cognitive, directly affecting consumers' ability to understand the stimuli to which they are exposed, critically evaluate their own decisions, and contest practices that silently influence their behavior. Freedom remains legally recognized yet functionally captured.

This dynamic also produces significant effects on free competition.

When competitive advantage derives less from product quality, price, or innovation and more from the capacity to intervene in consumers' internal decision-making processes, competition shifts to less visible layers that are difficult to access through traditional antitrust enforcement tools. As a result, cognitive barriers to entry emerge, grounded in the concentration of data infrastructure, proprietary predictive models, and cumulative algorithmic learning, conferring strategic advantages that are difficult to replicate and reducing market contestability.

This legal-economic interpretation finds empirical and forward-looking reinforcement in the *Global Risks Report 2026*, published by the World Economic Forum, which identifies so-called "frontier technologies" capable of interacting with human cognition as central vectors of systemic risk in contemporary societies. By associating such technologies with phenomena such as the erosion of civil rights, loss of institutional trust, intensification of power asymmetries, social polarization, and weakening democratic cohesion, the report demonstrates that the impacts of the cognitive economy extend beyond the individual level and assume a structural dimension affecting markets and institutions alike.

From the perspective of Economic Law, this diagnosis is particularly significant, as it confirms that practices capable of inferring or modulating mental states

generate not merely diffuse risks, but negative cognitive externalities with the potential to undermine the rationality of decision-making processes that sustain freedom of initiative and free competition. When public trust deteriorates due to perceptions of invisible manipulation, excessive surveillance, or exploitation of mental vulnerabilities, the outcome is not only the violation of individual rights, but the disorganization of markets themselves, marked by investment retrenchment, regulatory instability, and adverse social reactions.

The *Global Risks Report 2026* further emphasizes that the absence of adequate governance for emerging technologies tends to amplify risks rather than mitigate them, transforming regulatory failures into accelerators of institutional crises.

This observation directly aligns with the understanding that regulation of the cognitive economy cannot be merely reactive or sectoral, but must function as an anticipatory instrument for market organization, oriented toward preserving decisional autonomy, reducing cognitive asymmetries, and building trust as essential economic infrastructure.

In this sense, the World Economic Forum's report reinforces the view that regulating the cognitive economy does not constitute an exception to the constitutional economic order, but rather a necessary response to emerging risks that simultaneously affect the freedom of economic agents to act, competitive integrity, and the democratic legitimacy of markets. By recognizing the human mind as a new territory of systemic risk, the *Global Risks Report 2026* converges with the approach advanced here: regulating the cognitive economy is a condition for preserving the very functioning of the market economy in complex democratic societies.

It is precisely in this context that regulation assumes a central role as an instrument for the constitutional organization of the cognitive economy.

By setting limits on the use of cognitive inferences, imposing transparency obligations, requiring prior and continuous impact assessments, and establishing mechanisms of independent oversight, the State does not restrict freedom of initiative, but requalifies it, ensuring that it is exercised in a manner compatible with consumers' freedom to act and with the preservation of genuinely competitive markets. This is a core function of Economic Law, which recognizes the State as a normative and regulatory agent responsible for structuring the market to prevent undue concentrations of power and to preserve systemic rationality.

At this juncture, the notion of trust as infrastructure emerges as an essential element articulating regulation, economic freedom, and market stability. Technologies that operate upon the human mind require high levels of social legitimacy, given that their effects are often invisible, cumulative, and difficult for individuals to perceive. Trust, however, cannot be treated as a subjective presupposition or as a spontaneous by-product of market relations. It must be institutionally constructed, through clear norms, verifiable transparency mechanisms, accountability structures, independent oversight, and continuous risk assessment.

Within the cognitive economy, trust performs a dual function. On the one hand, it protects individuals by reducing cognitive asymmetries and enhancing their capacity to understand, critically assess, and contest economic practices. On the other hand, it operates as a collective economic asset, reducing uncertainty, mitigating

regulatory and reputational risks, and fostering long-term investment in responsible innovation. Markets devoid of trust tend to provoke adverse social reactions, normative fragmentation, and abrupt interventions, undermining both freedom of initiative and free competition.

The cognitive economy thus demonstrates that regulation does not constitute an exception to, or an obstacle within, the constitutional economic order, but rather its necessary unfolding in response to new forms of value creation and the exercise of economic power. By reinterpreting freedom of initiative as freedom to act, recognizing cognitive asymmetry as a relevant factor of power concentration, and treating trust as indispensable regulatory infrastructure, we reaffirm the historical function of Economic Law: to organize markets in accordance with constitutional values.

In this new scenario, regulating does not mean slowing innovation but defining the institutional boundaries within which innovation may occur in a legitimate, competitive, and socially sustainable manner. The cognitive economy can only consolidate itself as a viable economic activity when anchored in regulatory structures capable of protecting individual decisional autonomy, containing subtle abuses of power, and producing durable institutional trust. It is within this equilibrium – between economic freedom, regulation, and trust – that the key lies to reconciling technological innovation with the constitutional economic order in the twenty-first century.

4. The role of companies in the governance architecture of the cognitive economy: institutional responsibility, trust, and market legitimacy

Cognitive economy's consolidation not only shifts the traditional boundaries of economic activity, but also profoundly redefines the role of companies in shaping the governance of contemporary markets. In an environment in which value creation increasingly involves systematic inferences about mental states, cognitive processes, and internal decision-making dynamics, private actors no longer occupy a merely passive position *vis-à-vis* state regulation. Instead, they assume a structuring role in the production of legitimacy, institutional stability, and social trust.

Within this new economic configuration, corporate conduct can no longer be adequately understood through a strictly formal logic of regulatory compliance.

The high technical complexity of the solutions employed, combined with the inherent opacity of algorithmic systems and the speed at which they diffuse, means that a significant portion of the social and economic risks associated with the cognitive economy materializes even before the consolidation of specific regulatory frameworks. In this context, the absence of internal governance structures does not merely represent a future legal risk, but rather an immediate factor in the erosion of public trust, the weakening of market legitimacy, and the intensification of reactive and fragmented regulatory responses.

This dynamic stems from the fact that the cognitive economy operates on dimensions of human experience that are simultaneously sensitive, invisible, and cumulative. The effects of corporate practices on individuals' decisional autonomy rarely manifest as isolated or punctual events; instead, they tend to accumulate progres-

sively through repeated inferences, the continuous refinement of predictive models, and the silent modulation of choice architectures.

Under these conditions, corporate responsibility cannot be reduced to ex post compliance with legal commands. It must instead be understood as a continuous duty to assess, mitigate, and make explicit cognitive risks, integrated into the very design of business models.

The governance of the cognitive economy therefore requires companies to incorporate, within their decision-making processes and organizational structures, mechanisms capable of rendering visible and controllable practices that, by their very nature, tend toward opacity. Robust policies of algorithmic transparency, prior and ongoing cognitive impact assessments, independent auditing mechanisms, and effective accountability channels cease to be ancillary compliance tools and assume a central economic function. Such mechanisms operate as vectors for rebalancing cognitive asymmetries, preserving individuals' freedom to act and sustaining the trust indispensable to the regular functioning of markets.

It is at this point that trust ceases to appear as a merely rhetorical value or reputational strategy and comes to be understood as institutional infrastructure for economic activity. In markets where consumers, workers, and users are unable to directly perceive how their decision-making processes are being inferred, anticipated, or modulated, trust cannot rest on promises, corporate narratives, or formal consent. It must be constructed through verifiable parameters capable of translating legal and ethical principles into operational criteria subject to objective evaluation.

Initiatives aimed at measuring and comparatively assessing corporate practices – such as the NeuroTrust Index, currently being developed by our Global Future Council on Neurotechnology at the World Economic Forum – are situated precisely within this effort to institutionalize trust. By offering objective indicators of responsibility, transparency, and respect for cognitive autonomy in the use of sensitive technologies, the NeuroTrust Index helps shift trust from the declaratory plane to the structural one.

For companies, this represents not merely a symbolic distinction, but a strategic economic asset capable of reducing regulatory uncertainty, mitigating reputational risk, and fostering long-term, trust-oriented investment decisions.

From a systemic perspective, mechanisms of this kind play a relevant role in organizing markets themselves, by enabling economic choices – including decisions related to consumption, investment, and contracting – to incorporate criteria associated with cognitive integrity and responsible governance. Trust, in this sense, functions not only as a form of individual protection, but also as a stabilizing element of competition, preventing competitive advantages from being built upon the opaque exploitation of cognitive vulnerabilities.

The centrality of corporate action in the governance of the cognitive economy thus reinforces the understanding that state regulation and responsible self-regulation do not operate on antagonistic planes, but rather on complementary ones. In environments marked by accelerated innovation, the absence of verifiable corporate commitments tends to provoke more rigid, fragmented, and reactive regulatory responses. Conversely, the anticipatory incorporation of trust-based governance structures

expands the space for legitimate economic freedom, demonstrating that innovation can flourish without undermining fundamental constitutional values.

Conclusion

The analysis developed throughout this article supports the conclusion that the cognitive economy does not represent a mere continuation of the digital economy, but rather a qualitative inflection in how economic value is conceived, produced, and appropriated. By integrating internal processes of will formation into market circuits, this new economic configuration shifts the focus of regulation toward a dimension previously treated as a silent presupposition of economic activity: individuals' cognitive autonomy.

This shift poses substantive challenges to Economic Law and to the constitutional organization of markets. Regulatory instruments designed to protect material goods, external information, or observable conduct prove insufficient when the exercise of economic power comes to operate upon the invisible architecture of decision-making itself. In such contexts, preserving freedom of initiative does not mean reducing normative density; on the contrary, it requires recognizing regulation as a condition of possibility for economic freedom as a socially legitimate practice.

Reinterpreting freedom of initiative as freedom to act, identifying cognitive asymmetries as new forms of power concentration, and recognizing trust as a collective institutional asset allow the cognitive economy to be reconnected to the structural principles of Article 170 of the Brazilian Federal Constitution. Far from restricting the market, this approach reaffirms its democratic and social function, ensuring that technological progress does not become a silent mechanism for capturing human autonomy.

Within this framework, the role of companies assumes unprecedented relevance. The governance of the cognitive economy cannot be delegated exclusively to the State, nor can it rest on voluntarist commitments devoid of verifiability. The construction of legitimate and stable markets requires the incorporation of institutional mechanisms capable of translating legal and ethical values into concrete, measurable practices subject to public scrutiny—particularly those oriented toward consolidating trust as economic infrastructure.

Ultimately, the cognitive economy can only assert itself as a viable economic activity when anchored in regulatory and corporate arrangements capable of protecting individuals' decisional autonomy, containing subtle forms of abuse of power, and producing durable institutional trust. If the cognitive economy reorganizes the market around the mind, it falls to the constitutional economic order to reorganize it around freedom. It is within this equilibrium—between innovation, regulation, and trust—that not only the future of markets is shaped, but also the quality of economic life in contemporary societies.

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Litigation against neurotechnology companies: challenges, early cases, and future directions[1]

SEBASTIAN SMART[2]

Introduction: from AI litigation to neurotechnology litigation

The rapid expansion of neurotechnology marks a decisive new phase in the relationship between law, technology, and human rights (Ienca and Andorno, 2017; Yuste et al., 2017). As brain–computer interfaces, neural implants, and wearable EEG devices move from research to commercial and medical use, they bring with them the capacity to access, record, and influence human thought (OECD, 2019). These developments challenge traditional legal categories of harm, autonomy, and consent, raising fundamental questions about how the law protects cognitive integrity and mental privacy (Bublitz, 2013; Ligthart, Bublitz & Alegre, 2023). Despite the growing policy debate on neurorights (Yuste, 2023; Ienca et al., 2022), judicial responses remain fragmented and largely unexplored. This chapter addresses that gap by examining how litigation is beginning to frame accountability for neurotechnology companies, what legal strategies are emerging, and how these cases may shape the normative foundations of mental privacy in the years ahead.

[1] This chapter benefited from the contribution of James Clift, a Law student at Anglia Ruskin University.

[2] Senior Research Fellow in Access to Justice, Law and Technology at Anglia Ruskin University (Cambridge, United Kingdom). PhD in Latin American Studies and Human Rights from University College London, as well as an MA in Human Rights from the same institution. sebastian.smart@aru.ac.uk

Recent developments in litigation around emerging technologies have demonstrated that courts are increasingly central to the governance of digital innovation. Previous scholarship on legal mobilisation and strategic litigation has demonstrated how individuals and civil society organisations deploy legal action as a means of contesting structural power and influencing policy agendas (Vanhala, 2017; Handmaker, 2023). Building on these insights, recent work on AI-related cases has shown how such strategies are increasingly applied to challenge opacity, discrimination, and accountability gaps in automated systems (Smart and Oyarzún, 2025). These findings offer a useful conceptual foundation for examining how similar forms of mobilisation are now emerging in the neurotechnology field. Unlike AI systems that infer patterns from behavioural or biometric data, neurotechnologies access and manipulate information from within the human brain itself. Brain–computer interfaces (BCIs), wearable EEG headsets, and neural stimulators blur the line between body and mind, exposing new forms of vulnerability (Ligthart, Bublitz and Alegre, 2023). The potential harms are not limited to physical or emotional injury but extend to cognition, identity, and autonomy.

While litigation directly targeting neurotechnology companies remains rare, early examples already indicate how courts are beginning to grapple with these challenges. The first judicial and regulatory interventions—though limited in number—signal a gradual yet significant shift in how legal systems perceive cognitive and mental harms. Courts are no longer addressing only questions of data misuse or algorithmic bias, as in earlier waves of AI litigation, but are now confronted with issues that reach the very core of human subjectivity: thought, intention, and emotional states. The emerging case law, albeit fragmented, reveals the law's struggle to adapt traditional categories of injury, consent, and liability to technologies capable of interacting with the brain. By tracing these developments, this chapter argues that neurotechnology litigation extends ongoing debates around AI accountability into a new and more intimate domain — the human mind, and more broadly the peripheral nervous system — where the boundaries between bodily integrity, cognitive autonomy, and informational privacy become increasingly blurred.

Accordingly, the chapter proceeds in five integrated parts. Section 2 outlines the conceptual continuity and key points of divergence between litigation involving artificial intelligence and neurotechnology, situating emerging neural claims within broader theories of legal mobilisation. Section 3 surveys early judicial and regulatory developments, expanding on the analysis of *Girardi v Emotiv Inc.* developed in previous work (Smart and Oyarzún, 2024; Smart and Oyarzún, 2025) to include new comparative examples from the United States and the United Kingdom. Section 4 maps the principal legal pathways through which claimants may pursue accountability—ranging from product liability and data protection to constitutional and hybrid actions—integrating discussion of the doctrinal, evidentiary, and institutional barriers that shape each route. Finally, Section 5 examines the strategic and normative implications of these developments, outlining how test cases, judicial reasoning, and advocacy networks are collectively shaping a future litigation agenda for the protection of cognitive integrity.

1. Continuity and divergence from AI litigation

Strategic litigation has long been understood not merely as a legal tool, but as a broader form of political and social mobilisation. Scholars of legal mobilisation and cause lawyering have shown that litigation can function as a catalyst for policy reform, norm diffusion, and rights recognition, particularly in contexts where traditional political channels are unresponsive or inaccessible (McCann, 1994; Vanhala, 2012; Handmaker, 2023). Rather than viewing courts as neutral arenas, this body of work understands them as sites where legal actors translate social grievances into justiciable claims and, in doing so, reshape the boundaries of law and power. This conceptual lens offers valuable insights for examining how emerging technologies—and the harms they generate—become subjects of legal contestation.

The theoretical frameworks applied to legal mobilisation, including AI litigation—such as political disadvantage (Cortner, 1968; Vose, 1959), resource mobilisation (Galanter, 1974; Vanhala, 2012), legal opportunity structures (Hilson, 2002; Andersen, 2006), and framing (Marshall, 2003; Buhmann, 2023)—remain valuable for understanding how actors engage with neurotechnology. Previous research applying these frameworks to AI litigation argued that strategic legal mobilisation functions both as a form of resistance and as a mechanism of normative innovation, enabling claimants to use the courtroom as a site to redefine accountability in contexts where regulation lags behind technological change (Smart and Oyarzún, 2025). However, while this perspective provides a strong analytical foundation, its direct application to neurotechnology may encounter limitations. The intimate and embodied nature of neural data introduces forms of harm and evidentiary complexity that exceed the categories traditionally used in AI litigation. These features require reconsidering how concepts such as power asymmetry, resource dependency, and opportunity structures operate when the contested object is not data *about* individuals but data *from within* the human mind itself.

A mixed approach—acknowledging the interplay of structural conditions, strategic agency, and resource mobilisation—is therefore essential to understanding litigation in this emerging field. In the neurotechnology context, political disadvantage may manifest through epistemic dependency on corporate expertise; resources extend beyond financial means to include scientific and ethical literacy; and opportunity structures are shaped by the absence of clear regulatory regimes and the nascent status of neurorights. Analysing these dynamics together allows for a more precise understanding of how litigants address the distinctive challenges of neural harm and cognitive intrusion.

First, the nature of harm is internal and cognitive rather than external or behavioural. Neural data reflect the processes of thought itself, transforming privacy into a question of mental sovereignty (Yuste, 2023). Second, the evidentiary challenge is considerably higher: plaintiffs must demonstrate that neural manipulation or data processing produced a measurable change in cognition or mental state, a task complicated by scientific uncertainty (Rainey, 2024). Third, the normative dimension extends beyond familiar rights to privacy or non-discrimination, touching on mental integrity, autonomy, and the emerging notion of cognitive liberty (Ligthart et al., 2023).

These divergences amplify the asymmetries already observed in AI litigation. Neurotechnology companies hold exclusive control over the technical infrastructure and data necessary to assess causation or harm. As a result, litigation in this area exposes an even deeper imbalance between technological power and individual rights, highlighting the urgency of legal frameworks capable of addressing cognitive intrusion.

Methodologically, this chapter builds on and extends earlier research on litigation against AI companies by applying a similar analytical lens to a new and less explored domain. Through doctrinal analysis of a small set of emblematic cases, combined with comparative examination of judicial reasoning and regulatory interventions, it seeks to identify how neurotechnology litigation is beginning to shape the contours of accountability and rights protection. By focusing on deep-dive, small-N case studies rather than large-scale mapping, the chapter aims to complement the existing literature on strategic litigation—this time situating it within the emerging field of neurotechnology and the evolving jurisprudence of cognitive integrity.

2. Early cases and emerging patterns

Building on the discussion above, this section examines how the dynamics of strategic mobilisation, opportunity structures, and power asymmetries identified in AI litigation begin to manifest in the neurotechnology field. Although judicial engagement with neurotechnology remains limited, the first cases already reveal how courts and regulators are testing the boundaries of existing legal doctrines in response to new forms of cognitive and data-related harm. By analysing a small set of emblematic decisions across different jurisdictions, the section identifies emerging patterns in judicial reasoning, regulatory oversight, and rights articulation. Rather than seeking exhaustive coverage, the purpose is to trace how the law is gradually constructing a vocabulary of accountability for technologies that interact directly with the human mind.

2.1. Chile: Girardi v. Emotiv Inc.

The case *Girardi v. Emotiv Inc.* arose from a *recurso de protección* (constitutional protection action) filed before the Supreme Court of Chile in 2023 by Senator Guido Girardi, a long-time advocate of digital-rights and neuroethics regulation. The claim was directed against Emotiv Inc., a U.S.-based company marketing the "Emotiv Insight" consumer EEG headset, which records and transmits users' brainwave data for research and product-development purposes. Girardi argued that his neural data—collected while testing the device—had been stored and processed abroad without his explicit and informed consent, violating constitutional guarantees of privacy and psychological integrity protected under Articles 19(1) and 19(4) of the Chilean Constitution (Cornejo-Plaza, Cippitani and Pasquino, 2024). The action was presented as a constitutional remedy rather than a civil or administrative suit, reflecting Chile's tradition of using constitutional litigation to address emerging technological harms in the absence of specific regulation (Smart and Oyarzún, 2024).

The case rapidly became emblematic within Chile's broader debate on "neurorights," a concept promoted by scientists and legislators to safeguard mental privacy, personal identity, free will, and equitable access to neurotechnology (Ienca and Andorno, 2017; Yuste, 2023). It demonstrated how constitutional litigation can operate as a substitute for regulatory enforcement, particularly when technological innovation outpaces legislation. The *Girardi* action reframed a consumer-device dispute as a matter of fundamental rights, setting a global precedent for recognising neural data as an extension of personal integrity. It also reflected how political actors can use courts strategically to advance public awareness and institutional change—turning an individual grievance into a normative test case (Vanhala, 2012; Handmaker, 2023).

From the perspective of legal-mobilisation theory, *Girardi* exemplifies how strategic litigation can emerge through the interaction of structures, agency, and resources (Smart and Oyarzún, 2025). The political opportunity structure was unusually open: Chile's Supreme Court has a history of expansive constitutional interpretation, and the legal framework had recently evolved to include explicit protections for personal data and mental integrity. By the time of the 9 August 2023 ruling, Chile already had two relevant constitutional guarantees: (i) personal data protection was expressly recognised in 2018 via Law 21.096, which amended Article 19(4); and (ii) in October 2021 Chile became the first country to constitutionalise so-called neurorights through Law 21.383, adding that scientific and technological development must serve people and respect their physical and mental integrity (including brain activity). In parallel, Congress was overhauling the statutory data-protection regime—a process that concluded with Law 21.719 (published 13 December 2024). The Supreme Court's decision therefore operated within this already reformed constitutional landscape, using the *recurso de protección* to operationalise these guarantees in the context of a consumer neurotechnology device.

Girardi, as a senator with access to expert networks in neuroscience and human-rights law, mobilised substantial informational and symbolic resources to frame the dispute in human-rights terms. Yet the case also revealed limitations typical of resource-asymmetry contexts: the absence of technical expertise within the judiciary, reliance on academic testimony rather than regulatory evidence, and the difficulty of demonstrating harm in the absence of direct injury. These factors highlight the epistemic dependence of litigants on corporate data and the challenge of evidentiary transparency in neurotechnology disputes (Rainey, 2024).

The Supreme Court ultimately held that the collection and retention of brainwave data without specific consent violated the constitutional rights to psychological integrity and privacy, ordering the deletion of the claimant's data and suspending the commercialisation of the device until compliance could be verified (Rol N.º 1.080-2020). The judgment's key innovation was its explicit recognition that neural data fall within the scope of constitutional protection, applying for the first time Chile's 2018 and 2021 constitutional reforms to a concrete dispute. Nonetheless, the ruling's implementation exposed significant institutional weaknesses: there was no specialised authority to oversee compliance, enforcement mechanisms remained ambiguous, and no broader regulatory reform followed immediately (Smart and Oyarzún, 2024). Despite these limitations, *Girardi v. Emotiv Inc.* stands as a foundational precedent in

the jurisprudence of cognitive integrity, illustrating both the transformative potential and structural fragility of early neurotechnology litigation.

2.2. United States: regulatory and compliance actions

In the United States, early legal action involving neurotechnology companies has arisen primarily through regulatory enforcement rather than private tort litigation. The most prominent example is the 2023 settlement between the Department of Justice (DOJ) and Evoke Neuroscience Inc., a New York-based company marketing the *eVox* brain-mapping system designed to assess cognitive function and emotional states through EEG and event-related potentials. The DOJ alleged that Evoke and its CEO had violated the False Claims Act (31 U.S.C. § 3729 et seq.) by promoting the use of improper billing codes for reimbursement under federal health programmes, thereby submitting false claims to Medicare. Without admitting liability, Evoke agreed to pay US $445,000 and to implement compliance measures to prevent future violations (U.S. Department of Justice, 2023). Although the dispute did not concern neural harm or privacy, it remains one of the earliest enforcement proceedings against a company whose core business involves the commercialisation of neurotechnology for health diagnostics.

The *Evoke* settlement illustrates the distinctive trajectory of neurotechnology governance in the United States, where regulatory mechanisms often substitute for judicial review in the absence of a comprehensive federal framework for neurodata protection. Enforcement actions under existing statutes—such as the False Claims Act, the Food, Drug and Cosmetic Act, and Federal Trade Commission (FTC) rules—serve as indirect means of accountability, focusing on marketing integrity, billing accuracy, and consumer protection rather than on cognitive rights. These interventions demonstrate how state capacity can shape the early stages of technological regulation: rather than victims initiating test cases, it is public agencies that act pre-emptively to deter misconduct. In this sense, U.S. neurotechnology litigation emerges not from claims of injury but from concerns about compliance, echoing patterns previously observed in broader frameworks of technological accountability, where governance relies on compliance mechanisms and soft-law enforcement rather than formal adjudication (Buhmann, 2023; Smart and Oyarzún, 2025).

From the perspective of strategic-litigation theory, the *Evoke* case demonstrates a markedly different configuration of actors and opportunity structures than that seen in Chile. The plaintiffs were not individuals or advocacy groups but the federal government itself—an example of state-led mobilisation (Vanhala, 2012). Here, agency and resources were concentrated within the Department of Justice and the Office of Inspector General, whose investigative authority replaced the evidentiary asymmetries that typically disadvantage private litigants. The legal opportunity structure was shaped by the flexibility of U.S. administrative law, which allows enforcement through settlement without the need for judicial precedent. Yet this model has limitations for rights development: because cases are resolved administratively and often confidentially, they do not generate publicly reasoned jurisprudence or establish doctrines on cognitive or mental-data protection. As a result, while the U.S. enforcement apparatus is robust in addressing fraud or misleading conduct, it remains ill-equipped

to articulate principles of mental privacy or *cognitive liberty* (Rainey, 2024; Yuste, 2023).

The DOJ's press release (2023) framed the *Evoke* settlement as part of a broader commitment to ensuring the integrity of billing practices for emerging neurodiagnostic technologies. The resolution required Evoke Neuroscience to strengthen its compliance programme and cooperate with ongoing oversight, but it involved no judicial findings of fact or law. This absence of judicial reasoning highlights the current enforcement gap: while administrative settlements can correct corporate misconduct, they do little to advance normative understanding of neural harms. Nevertheless, the case contributes to an emerging compliance culture among neurotechnology firms, signalling that agencies will scrutinise claims about brain-related products with the same rigour applied to medical devices and AI-based diagnostics.

A parallel example of preventive oversight can be found in the investigations targeting Neuralink, the brain-implant company founded by Elon Musk. In late 2022, U.S. federal authorities launched multiple inquiries following allegations of animal welfare violations during preclinical trials, including the rapid killing of test monkeys in experiments at the University of California, Davis (Levy, 2022). Subsequent reports in 2024 revealed further probes by the U.S. Department of Transportation for breaches of hazardous material transport rules after the company allegedly failed to properly label and secure containers carrying implant materials removed from animal subjects (Reuters, 2024). In December 2024, the Securities and Exchange Commission (SEC) also reopened an investigation into Neuralink concerning potential misstatements to investors regarding the timing of human trials and device safety. None of these proceedings have resulted in criminal charges or judicial findings, yet together they show a pattern of regulatory intervention that precedes any rights-based litigation.

These parallel developments reveal that, in the United States, the governance of neurotechnology is taking shape primarily through administrative enforcement rather than adjudicative precedent. Agencies such as the DOJ, the FTC, and the SEC act as first responders, policing claims of safety, fraud, and compliance before questions of cognitive liberty or neural privacy reach the courts. This model of preventive governance reflects both the strength and the limitation of the U.S. legal opportunity structure: it provides swift intervention and deterrence but leaves unresolved the substantive articulation of mental integrity as a legally protected interest. As a result, the law's engagement with neurotechnology in the U.S. context is likely to evolve first through regulatory enforcement and only later through rights-based adjudication.

2.3. United Kingdom: consumer protection and advertising oversight

In the United Kingdom, early regulatory action concerning neurotechnology has arisen through consumer protection and advertising oversight rather than through judicial or constitutional litigation. A key example is the 2024 decision of the UK Advertising Standards Authority (ASA) against Flow Neuroscience AB, a Swedish company marketing a transcranial direct-current stimulation (tDCS) headset designed to alleviate symptoms of depression. The company's advertisements claimed that the device was "clinically proven" to treat depression and improve mood without medication. Following consumer complaints, the ASA investigated these statements and

found that the supporting clinical evidence was insufficient to substantiate the therapeutic claims. In its ruling, the regulator ordered Flow Neuroscience to withdraw or amend its advertising across digital platforms and to ensure that any future marketing made clear the limits of the available scientific data (ASA, 2024).

Although the ASA decision did not arise from a court proceeding, it represents one of the earliest regulatory actions in the UK directly addressing cognitive-affecting consumer technologies. The case underscores how consumer-protection frameworks-particularly those concerning misleading advertising and health claims are becoming de facto tools for neurotechnology oversight. In the absence of a dedicated EU or national legal framework on neurodata or mental integrity, regulators have relied on existing instruments such as the UK Consumer Protection from Unfair Trading Regulations 2008 and EU Directive 2005/29/EC on Unfair Commercial Practices to discipline the commercial rhetoric of neurotechnology firms. The *Flow Neuroscience* decision thus signals an important normative development: claims about the brain are subject to the same evidentiary rigour as medical or pharmaceutical assertions, reflecting regulators' growing sensitivity to the psychological and ethical implications of such products (Yuste, 2023).

From a strategic-litigation perspective, *Flow Neuroscience* illustrates how regulation can substitute for judicial mobilisation when opportunity structures for litigation are weak. Whereas in *Girardi* individuals mobilised constitutional rights, in the UK the initiative arose from institutional actors—a self-regulatory authority responding to public complaints. The agency of civil society was indirect yet significant: consumers triggered the process by invoking procedural avenues available under advertising-complaint mechanisms. Resource mobilisation was minimal but effective—no lawyers or expert witnesses were required, yet the outcome constrained a multinational's commercial strategy. Structurally, this reflects the UK preference for preventive and corrective governance over adversarial adjudication (Hilson, 2002; Andersen, 2006). The *Flow Neuroscience* case also highlights the role of *framing*: by positioning exaggerated therapeutic promises as a matter of consumer deception rather than health harm, regulators were able to act swiftly within their existing mandate (Smart and Oyarzún, 2025).

In its published decision, the ASA (2024) concluded that Flow Neuroscience's evidence base—consisting of small clinical trials and self-reported outcomes—did not meet the threshold for substantiating medical efficacy claims. The regulator ruled that the advertisements breached CAP Code Rule 12.1 (Medicines, Medical Devices, Health-Related Products and Beauty Products) and ordered the company to refrain from implying that its device could "treat" depression. This outcome did not produce binding precedent but set a persuasive regulatory standard likely to influence other national authorities under the European Consumer Protection Cooperation Regulation (EU 2017/2394). More broadly, the case demonstrates how UK oversight bodies are beginning to apply existing consumer-law principles to emerging neurotechnologies, establishing a baseline of evidentiary transparency that could later inform judicial interpretations of cognitive integrity and informed consent. By treating misleading advertising as a form of cognitive risk, *Flow Neuroscience* illustrates how the UK model of incremental, administrative enforcement may gradually build the normative infrastructure for future rights-based neurotechnology litigation.

2.4. Analogous precedents

Because direct neurotechnology litigation remains limited, useful insight can be drawn from adjacent legal fields that have already grappled with technological risk, evidentiary uncertainty, and complex causation. Three areas are particularly instructive: (i) medical-device liability, where courts have long addressed questions of design defect and duty to warn; (ii) data-protection and biometric-privacy litigation, which tests the boundaries of informational self-determination; and (iii) algorithmic discrimination and surveillance cases, which explore accountability for opaque systems affecting fundamental rights. Together, these areas form a comparative laboratory for anticipating how courts may treat harms arising from neural interfaces and brain-data processing.

Within medical-device litigation, courts have progressively defined how technological risks intersect with bodily integrity. In *A v National Blood Authority* [2001] 3 All ER 289, the English High Court held that blood infected with hepatitis C constituted a "defective product" under the Consumer Protection Act 1987, even though the contamination was scientifically unavoidable. The ruling expanded strict liability by focusing on consumer expectations rather than producer fault—an approach that could inform future claims where neural devices cause unexpected cognitive or emotional effects. A later case, *Wilkes v DePuy International Ltd* [2016] EWHC 3096 (QB), refined that standard, stressing that courts must balance risks against the overall benefits of innovation and consider regulatory compliance. That proportional approach may likewise guide judges assessing whether the benefits of brain–computer interfaces justify certain neural risks.

Comparable developments in the data-protection field further broaden the concept of harm. In *Data Protection Commissioner v Facebook Ireland Ltd and Maximilian Schrems* (*Schrems II*) [C-311/18] (2020), the Court of Justice of the European Union invalidated the EU–US Privacy Shield framework, finding that U.S. surveillance laws failed to guarantee equivalent protection for personal data. The decision extended privacy beyond economic interests, recognising dignity and autonomy as substantive harms. Its reasoning—particularly regarding cross-border transfers—offers clear analogies for disputes involving neural data stored or analysed outside a claimant's jurisdiction, as in *Girardi v Emotiv Inc.*

Finally, in the context of algorithmic monitoring, the European Court of Human Rights in *López Ribalda and Others v Spain* (2019) ECHR 187 balanced workplace surveillance against employees' privacy under Article 8 of the Convention. The Grand Chamber ultimately upheld covert video monitoring as proportionate to the employer's legitimate aim, illustrating how proportionality tests structure judicial reasoning when technology captures or infers information about individuals without consent. Neurotechnology that records or interprets brain signals could invite similar scrutiny under privacy and dignity frameworks.

From a strategic-litigation perspective, these adjacent fields demonstrate how claimants can overcome asymmetries of power and information. In medical-device class actions, plaintiffs mobilised expert networks and collective resources to translate diffuse harms into legally cognisable injury—an approach likely indispensable in neural-harm cases. Data-protection activism by organisations such as NOYB and Privacy International shows how repetitive test cases and strategic framing can build

precedent even in technically complex domains. Likewise, litigation on algorithmic discrimination underscores the importance of aligning individual grievances with public narratives about fairness, transparency, and accountability (Smart and Oyarzún, 2025). These patterns suggest that effective neurotechnology litigation will depend on coalitions between scientists, human-rights advocates, and consumers who can articulate neural harms within established doctrinal categories.

Across these domains, courts have gradually extended the notion of harm from tangible injury to violations of autonomy and informational control. *A v National Blood Authority* established that safety expectations prevail even over scientific uncertainty; *Wilkes v DePuy* introduced proportionality and regulatory deference; *Schrems II* framed privacy as a transnational human right; and *López Ribalda* demonstrated how proportionality mediates conflicts between technological surveillance and personal dignity. Collectively, these precedents reveal both opportunity and constraint for neurotechnology litigation: they provide analogical footholds for recognising cognitive and neural harms, yet their evidentiary and proportionality standards may restrict judicial willingness to innovate. As in earlier phases of data- and algorithm-related jurisprudence, the evolution of neurotechnology law will likely proceed incrementally—through adaptation of these doctrines toward a hybrid field integrating bodily integrity, informational autonomy, and cognitive liberty.

3. Legal pathways and barriers

The preceding cases reveal how litigation against neurotechnology companies is beginning to crystallise across different legal fields. Each of these avenues—civil liability, data protection, constitutional and human-rights law, and hybrid actions—offers a potential route to accountability, yet each is constrained by its own doctrinal and evidentiary limits. Rather than existing as separate phases of litigation, these barriers are intrinsic to the legal frameworks themselves: the same rules that enable claimants to seek redress also define the obstacles they face.

3.1. Product liability and tort claims

Civil liability remains the most immediate yet least developed route for individuals harmed by neurotechnological devices. Potential claims include negligence, defective design, and failure to warn, echoing classic product-liability doctrines. Plaintiffs could allege that a neural interface—such as a brain stimulator or EEG headset—was marketed without adequate disclosure of cognitive or psychological risks. However, causation is exceptionally difficult to prove. Establishing that a device directly produced a change in cognition or mood requires complex neuroscientific evidence, exclusion of alternative causes, and access to proprietary data controlled by manufacturers (Rainey, 2024).

These evidentiary constraints reproduce the asymmetries seen in medical-device litigation. In *A v National Blood Authority* [2001] the court prioritised consumer expectations over producer fault, while in *Wilkes v DePuy International Ltd* [2016] it adopted a more manufacturer-friendly proportionality test, weighing innovation benefits against risk. Neurotechnology litigation will likely oscillate between these two poles—strict protection of users versus judicial deference to innovation. Because

regulators have yet to define standards for "neural safety," courts may hesitate to impose liability absent clear statutory guidance. Plaintiffs therefore face what Galanter (1974) called the "repeat-player advantage": firms control the data and expertise necessary to establish causation, leaving individuals epistemically dependent and procedurally disadvantaged (Smart and Oyarzún, 2025).

3.2. Data protection and mental privacy

Data-protection law provides a parallel and increasingly central pathway. Under the EU General Data Protection Regulation (GDPR), neural data would likely fall within "special categories" of sensitive information, akin to health or biometric data. Unauthorised processing, profiling, or transfer could therefore give rise to administrative fines or compensation claims. The Chilean Supreme Court's reasoning in *Girardi v Emotiv Inc.* demonstrated that courts can interpret privacy law expansively to encompass "mental privacy" and "psychological integrity" (Ligthart et al., 2023).

Yet the same doctrine that opens this path also limits it. Neural signals are dynamic and context-dependent, complicating definitions of consent, rectification, or erasure. Users rarely understand the inferential capacity of algorithms that transform raw brain activity into emotional or behavioural predictions. Consent thus becomes formal rather than substantive, undermining autonomy (Ienca and Andorno, 2017). Cross-border data flows—where devices transmit brain data to foreign servers—replicate the jurisdictional tensions seen in *Schrems II* (CJEU, 2020). While regulators can sanction unlawful processing, they cannot easily address deeper harms such as manipulation of thought or personality. The protection of "mental privacy" therefore remains conceptually ahead of its procedural enforceability.

3.3. Constitutional and human rights litigation

Constitutional and human-rights frameworks provide the most normatively ambitious but procedurally demanding route. Chile's 2021 constitutional reform (Law 21.383) explicitly recognised neurorights, mandating that scientific and technological development respect mental integrity and brain activity. Similar initiatives have emerged in Spain and Brazil, where legislators debate linking neurorights with protections for psychological continuity and cognitive liberty (Yuste, 2023). These constitutional provisions allow claimants to frame neurotechnological harms as violations of fundamental rights rather than consumer grievances.

The United Nations and many European authorities have likewise begun discussing the legal ethics of neurorights, with heavy focus on the rights to privacy (ECHR, Article 8), liberty and security of the person (ECHR Article 5) and the prohibition of inhuman or degrading treatment (ECHR, Article 3). In particular, a compilation of recommendations made to UN states by the *Special Rapporteur on the right to privacy* highlights concerns relating to access to neurodata (UN, A/HRC/58/58). Medical brain-computer interfaces potentiate interference with medical consent, and privacy. In cases concerning mental integrity, European courts apply doctrinal self-determination as an underlying principle. In *E.S. v Finland* [2024], the ECtHR emphasised the doctrines of informed consent and procedural safeguards in cases of involuntary medical treatment. The ECtHR, however, identified deficiencies in the availability of remedies at the state level, rather than recommending an absolute pro-

hibition on coercive intervention. This indirect pathway to litigation reflects earlier litigation trajectories for emerging technologies using existing rights frameworks. For brain-computer interfaces, such an approach provides limited recourse unless a tangibly observable injury can be demonstrated for judicial remedy, including tortious or compensatory relief.

Prospective neurodata breaches extend past normal digital privacy concerns as neurodata can comprise the intrinsic mechanisms of how an individual functions. A consumer technology sufficiently capable of reading neurodata may undergo 'function creep', extending the scope of use beyond the technology's original purpose, allowing alterations to brain chemistry (Bublitz et al., 2025). Such a prospect introduces new threats to a multitude of rights, including freedom of thought (ECHR, Article 9).

However, structural limitations persist. First, constitutional adjudication is slow and often reactive: courts require a concrete dispute before issuing guidance, leaving preventive oversight weak. Second, few jurisdictions possess specialised institutions to monitor compliance, as illustrated by the enforcement gap following *Girardi* (Smart and Oyarzún, 2024). Third, judges may be reluctant to recognise cognitive alteration or data misuse as a rights violation absent physical or economic injury—a manifestation of judicial conservatism rooted in evidentiary caution. Nonetheless, constitutional litigation remains strategically valuable: it enables advocacy networks to generate normative precedents, mobilise public attention, and pressure legislators to codify neurorights into positive law (Vanhala, 2012; Handmaker, 2023).

3.4. Hybrid and derivative actions

In practice, the complexity of neurotechnology means that effective litigation will likely involve hybrid or derivative claims that combine multiple doctrines. A single action may allege negligent design, unlawful data processing, and infringement of constitutional rights simultaneously. This cumulative strategy—observed in early AI cases—allows plaintiffs to navigate doctrinal uncertainty by presenting overlapping theories of liability (Hilson, 2002; Smart and Oyarzún, 2025).

Yet hybridity also introduces its own barriers. Different causes of action operate under distinct evidentiary standards and jurisdictions: data-protection claims fall under administrative law, tort under civil law, and constitutional petitions under public law. Coordination among these regimes is limited, producing procedural fragmentation and inconsistent remedies. Transnational elements, such as corporate group structures or cloud-based data processing, further complicate forum selection and standing. Nonetheless, hybrid actions remain a crucial tool for redistributing litigation risk and compelling judicial engagement with novel questions of cognitive integrity. They also illustrate how strategic litigants adapt within constrained opportunity structures—using the very multiplicity of legal forums to sustain normative pressure where any single pathway might fail.

Across these different routes, the challenges of causation, consent, institutional fragmentation, and judicial conservatism are not external impediments but defining features of the current phase of neurotechnology litigation. The law's engagement with the mind is being constructed through a patchwork of doctrines originally

designed for physical, informational, or emotional injury. Each framework offers partial solutions and partial blind spots: product-liability law provides procedural access but demands impossible proof; data-protection regimes safeguard information but not cognition; and constitutional litigation articulates rights without guaranteeing enforcement. Together they form a transitional architecture of accountability, one that reveals both the fragility and the promise of the emerging jurisprudence of mental integrity.

These intertwined pathways and barriers suggest that litigation is doing more than filling regulatory gaps—it is actively shaping how societies conceptualise the limits of technological intrusion into the human mind. The following section turns to the strategic and normative implications of this process, examining how courts, advocacy networks, and litigants are redefining accountability and advancing a nascent framework for cognitive rights through test cases and judicial reasoning.

4. Strategic and normative implications and future directions

The evolving jurisprudence of neurotechnology reveals that litigation is not simply a reactive mechanism for redress, but an active arena in which the boundaries of mental integrity, autonomy, and technological accountability are being negotiated. As courts begin to confront the distinctive harms of brain–computer interfaces and neural data processing, strategic litigation assumes a dual function: it challenges immediate corporate practices while simultaneously constructing the normative vocabulary through which cognitive rights are articulated. This section examines the broader implications of early neurotechnology cases for legal mobilisation, judicial reasoning, and the governance of emerging technologies, concluding with a research and policy agenda for the coming decade.

4.1. Litigation as a mechanism of normative innovation

In the absence of comprehensive regulatory frameworks, litigation operates as a site of norm creation. Early cases—such as *Girardi v Emotiv Inc.* in Chile or administrative enforcement in the United States—illustrate how courts and regulators can translate abstract ethical debates about neurorights into legally enforceable principles. Even when outcomes are narrow, they establish discursive precedents: recognising neural data as constitutionally protected, defining "mental privacy," or acknowledging cognitive harm as a distinct category of injury. These incremental developments mirror earlier phases in data-protection and algorithmic discrimination jurisprudence, where isolated judgments eventually consolidated into coherent legal doctrines (Smart and Oyarzún, 2025).

Strategic plaintiffs and advocacy organisations play a crucial role in this process. By framing individual disputes as tests of fundamental principles, they generate cases that function as laboratories of interpretation. Success depends not merely on legal victory but on shaping how judges, policymakers, and the public conceptualise the stakes of neurotechnology. This normative function distinguishes neurotechnology litigation from routine product or privacy claims: it is litigation as governance, performed in real time.

4.2. Strategic mobilisation and opportunity structures

Applying the analytical insights of legal mobilisation theory, neurotechnology cases reveal how litigation emerges from the interaction of opportunity structures, resources, and framing (Vanhala, 2012; Handmaker, 2023). The Chilean example demonstrates that favourable constitutional opportunity structures—combined with political advocacy and scientific expertise—can yield rapid normative innovation. By contrast, the U.S. experience underscores how enforcement-led governance, rather than rights-based adjudication, may delay the emergence of cognitive rights.

Effective mobilisation in this domain requires interdisciplinary coalitions. Lawyers, neuroscientists, data ethicists, and human-rights advocates must collaborate to translate cognitive harms into legally legible evidence. Civil-society organisations can provide institutional continuity across fragmented jurisdictions, supporting cumulative test litigation. Funding mechanisms, including philanthropic and academic partnerships, are essential to offset the structural advantage of well-resourced corporate defendants (Galanter, 1974). As early AI litigation demonstrated, the strategic sequencing of cases—beginning with clear procedural violations before advancing to substantive claims—can gradually reshape judicial sensibilities and regulatory expectations.

4.3. Judicial roles and the ethics of adjudication

The judiciary occupies a pivotal position in the governance of neurotechnology. Faced with epistemic uncertainty, courts must decide whether to defer to scientific authority or to assert interpretive leadership in defining cognitive rights. The Chilean Supreme Court's recognition of mental privacy demonstrates that courts can act as norm entrepreneurs—adapting constitutional principles to technological contexts even before legislators intervene. Yet such innovation entails ethical responsibility: premature doctrinal expansion risks overreach, while excessive restraint may entrench impunity.

A key future challenge will be the development of epistemic standards for adjudicating cognitive harm. Courts may need to adopt presumptive causation frameworks, appoint independent neuroscientific experts, or create specialised chambers for technological disputes. These procedural innovations could mitigate informational asymmetries while preserving judicial independence. At a broader level, the judicial acknowledgment of cognitive liberty may redefine the scope of personal autonomy, extending human-rights protection to the very processes of thought and emotion.

4.4. Building a future agenda for neurotechnology litigation

The next decade will likely determine whether neurotechnology litigation matures into a coherent field or remains a constellation of exceptional cases. Several research and policy priorities emerge from the analysis above:

a) Developing empirical evidence on cognitive harm. Rigorous interdisciplinary studies linking neural-device use to cognitive or psychological outcomes are essential to substantiate claims in court. Empirical data can help courts move beyond speculation and establish reliable thresholds for causation.

b) Clarifying consent and data governance models. Legislators and regulators should adapt existing data-protection and medical-device regimes to include explicit provisions on neural data—addressing informed consent, secondary uses, and algorithmic inferences.

c) Strengthening transnational cooperation. Given the global nature of neurotechnology markets, mutual-recognition frameworks for enforcement and jurisdictional coordination are necessary. Comparative jurisprudence—especially from the EU, Latin America, and regional human-rights systems—can accelerate doctrinal convergence.

d) Institutional innovation for cognitive rights. Establishing specialised oversight bodies, akin to data-protection authorities or bioethics councils, could provide expert guidance to courts and ensure post-judgment monitoring.

e) Expanding strategic litigation networks. Advocacy groups should coordinate to share legal strategies, expert resources, and case databases, similar to models used in environmental and digital-rights litigation. This will allow cumulative precedent-building across jurisdictions.

Concluding reflections

Litigation against neurotechnology companies sits at the frontier of law's encounter with the human mind. As neural devices blur the boundary between cognition and computation, courts become not only arbiters of liability but architects of moral and legal meaning. Early cases reveal the fragility of existing frameworks—dependent on analogies to bodily, informational, or emotional harm—but also their capacity for adaptation. Through strategic mobilisation, interdisciplinary cooperation, and sustained normative engagement, litigation can transform these isolated encounters into the foundations of a coherent jurisprudence of cognitive integrity.

Ultimately, the future of neurotechnology litigation will depend on whether courts, regulators, and advocates can move beyond the vocabulary of data and privacy to articulate a distinct legal recognition of the mind itself as a protected domain.

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The intersection of neuroeconomics and entrepreneurship: examining the risks of regulatory insufficiency in the neurotechnology sector

ANA MARIA D'ÁVILA LOPES[1]

Contents: Introduction; 1. Entrepreneurship and economic development; 2. The emergence of neuroeconomics; 3. Regulation of neurotechnology companies; Conclusion; References.

Introduction

This paper aims to analyze the advantages and disadvantages of using Neuroeconomics to foster entrepreneurship. According to Teixeira *et al*. (2020) entrepreneurship is as an effective strategy to combat unemployment and poverty, which are still strongly present in Brazil (IBGE, 2024). Through Neuroeconomics, it is possible to develop and strengthen the skills necessary to be sucessful entrepreneur, such as a lidership, self-confidence, adaptability and resilience.

However, the use of neurotechnologies may jeopardize neurorights, as neural liberty, identity, integrity, privacy, and equality, given the extant regulatory vacuum surrounding neurotechnology companies. It is not a matter of banning the use of neurotechnologies, but of seeking a balance between neuroscientific advances and the protection of human dignity.

Consequently, this paper begins by defining entrepreneurship and delineates the skills requisite for successful entrepreneurial activity, as well as its contribution to the economic development of a society. Subsequently, the emergence of Neuroeconomics is addressed, highlighting how the interface between Neuroscience, Neurotechnology, and Artificial Intelligence has revolutionized the understanding of decision-making and the behavior of *homo oeconomicus,* leading us to speak today of *homo neurobiologicus*. Finally, acknowledging the need to regulate neurotechnology companies to protect neurorights, international initiatives to regulate companies to protect

[1] Full Professor of Law at the University of Fortaleza (Brazil). Post-Doctorate in Law from the University of Auckland. PhD in Law from the Federal University of Minas Gerais. Research Productivity Fellow (PQ/CNPq-Brazil). anadavilalopes@unifor.br

human rights were briefly presented. Despite their relevance, these legislations remain insufficient, as most take the form of non-binding (soft law), creating a significant global regulatory gap that leaves individuals vulnerable to the rapid expansion of neurotechnologies.

The theme was developed through predominantly bibliographic research, also encompassing the analysis of international legislation, whose results were analyzed using the dialectical-discursive method, aiming to identify the positive and negative aspects of the various theoretical approaches and legislative initiatives. In conclusion, further studies are needed both to build a solid conceptual framework on neuroscientific and neurotechnological advances, considering their constant and rapid development, and to establish standards for regulating companies whose operations are expanding not only geospatially but also financially, further complicating the establishment of limits that reconcile neural technoscientific advancement with respect for human rights.

1. Entrepreneurship and economic development

Entrepreneurship is defined by Dornelas (2008) as the transformation of ideas into opportunities to enable the creation of new businesses. Costa, Barros, and Carvalho (2015), in turn, clarify that entrepreneurship encompasses functions, activities, and actions that can be directed both towards the creation of new businesses and towards the innovation of existing businesses.

According to Schumpeter (1942), the essence of entrepreneurship lies in the perception and use of resources, shifting them from their traditional use to new uses in order to optimize them, thus promoting the economic development of society.

In this vein, Teixeira et al. (2020, our translation) state that entrepreneurship is "source of development that promotes structural change and growth, while offering a path for socioeconomic improvement for individuals facing poverty and inequality" which directly contributes to the achievement of two of the Sustainable Development Goals (SDGs), launched by the United Nations (UN) in September 2015 (UN, 2015), to continue the Millennium Development Goals (MDGs) of 2000 (Lopes and Santos Junior, 2018). These two SDGs are the fight against poverty (SDG 1) and the reduction of inequalities (SDG 10).

The relevance of entrepreneurship is also highlighted by the Federation of Industries of the state of Ceará (FIEC), in a document prepared in partnership with the Ceará Industry Observatory "Entrepreneurship is a pivotal element in the dissemination of innovation within society, fostering the creation and consolidation of firms that drive a dynamic business environment" (Observatório da Indústria Ceará; FIEC, 2024, p. 43).

To these positive aspects of entrepreneurship, we can also add: (Empreendedorismo, 2023):

a) generation of new jobs.

b) source of innovation and introduction of new technologies and new solutions to problems in the business field.

c) promotion of competition, which results in lower prices and better product quality.

d) economic development of local communities.

e) fostering the social inclusion of vulnerable groups by enabling their economic independence.

It is worth pointing out, however, that authors such as Timmonds (2009) highlight other benefits of entrepreneurship that go beyond the economic field. Thus, for him, entrepreneurship, more than a new form of management to start or improve a business, has become a new paradigm of thinking and reasoning, becoming of interest to other fields of knowledge, such as medicine or engineering.

This conceptual shift is largely attributed to behavioral theories, which focus on the motivations and behavioral patterns of entrepreneurs. This field, often termed social entrepreneurship, is characterized by the identification of social exigencies and the development of "novel and enduring solutions for social groups, communities, or society at large through the cooperation of all stakeholders" (Spies, 2018, p. 22, our translation). Spies (2018) further notes that Max Weber was a pioneer of this behavioral school, identifying entrepreneurs as inherently independent and innovative agents.

Whether through its contribution to the field of business, as pointed out by economic theory, or to the social field, as indicated by behavioral theory, the fact is that entrepreneurship can play a fundamental role in the well-being of society, highlighting the importance of identifying and developing the skills that characterize a successful entrepreneur.

Indeed, entrepreneurs, in addition to knowledge in the field of business, need to possess certain skills, such as leadership, optimism, initiative, tolerance for ambiguity and uncertainty, flexibility, self-confidence, tenacity, energy, learning capacity, a tendency to trust people, etc. (Filon, 1999).

These skills need to be developed, which can be done through the implementation of public policies to promote an entrepreneurial culture and education. According o Schaefer and Minello (2016, p. 60, our translation), "The importance of entrepreneurial education for the development of a nation has been recognized, not only in Brazil, but in several countries around the world, having been placed as a priority on political, economic and academic agendas and debates, including the highest levels of discussion at the United Nations".

Building an entrepreneurial culture and education can not only foster the emergence of more entrepreneurs but can also contribute to reducing the high rates of closure of new businesses, also known as the "mortality rate" (Spies, 2018). In the most recent study on the subject, conducted by the Brazilian Institute of Geography and Statistics (IBGE) in 2022, it was identified that approximately 60% of companies close before 5 (five) years of being created (IBGE, 2023).

There are 4 (four) types of factors responsible for the closure of new businesses: a) management deficiencies, such as inadequate location; b) economic situation, such as the country's economic recession; c) operational logistics, such as a lack of qualified labor; and d) legal framework, such as a high tax burden (IBGE, 2023). Analyzing these factors, it is clear that a large part can be avoided or overcome with

adequate training for entrepreneurs, confirming that it is "imprescindível possuir conhecimento para que um negócio não morra ainda no seu início e venha a se tornar próspero" (Spies, 2018, p. 43).

The identification and development of the skills necessary for the success of an entrepreneur have gained a new ally today: Neuroscience, and more specifically Neuroeconomics, aimed at understanding, developing and altering people's economic behavior.

2. The emergence of neuroeconomics

Advances in the field of Neuroscience, especially neuroimaging, have shown the influence of emotions on people's economic behavior, giving rise to a new field of study called Neuroeconomics, defined as "the application of neuroscientific methods to analyze and understand economically relevant behavior" (Kenning; Plassmann, 2005, p. 344).

Kenning and Plassmann (2005) teach that classical economic theories worked with the idea of rational human beings, guided by self-interest and without emotions. Currently, advances in the field of experimental and behavioral economics have highlighted the limitations of these theories.

This change began in the seventies, when economics began to open to other fields of study such as psychology, giving rise to the concept of "economic behavior" from which new decision-making models were developed.

At the end of the 20th century, the analysis of so-called economic behavior gained significant momentum thanks to the tools of Neuroscience, which allow direct observation of brain structure and function. As Kenning and Plassmann (2005) state, we have moved from *homo oeconomicus* to *homo neurobiologicus*.

The main tools of Neuroscience for this type of analysis are electroencephalography (EEG), magnetoencephalography (MEG), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI), each with advantages and disadvantages.

> In summary, all currently available neuroimaging techniques have advantages and disadvantages. While the *Where* of brain activity is more easily assessed by fMRI or PET, the question of *when* – e.g. the discrimination between parallel and sequential processing – can be more precisely answered by EEG or MEG. Thus, the method (or even a combination of several techniques) should be chosen carefully, depending on the economic question to be answered (Kenning; Plassmann, 2005, p. 345).

Through these tools, brains are analyzed based on the stereotaxic coordinate system proposed by Talairach in 1967 and improved in 1988 with the help of Tournoux. Today, thanks to Artificial Intelligence, the brain atlas proposed by Talairach and Tournoux has gained a much more precise digital version, which offers more accurate and agile answers (Abdala *et al*., 2006).

These advances in the field of Neuroscience currently allow us to identify, with greater precision, the areas of the brain that correspond, for example, to speech, vision, intellectual abilities, and behavior, also allowing us to identify the areas where the most complex brain functions develop, such as decision-making and emotions (Kenning; Plassmann, 2005).

Before these advances, there were only two ways to know someone's preferences regarding, for example, the purchase of a particular product. One was through the application of a questionnaire. The other was by directly observing the consumer's behavior. Today, this can be accomplished via tools such as eye-tracking (Guo; Kwon, Hwang; Zhou, 2023)

The uses of these advances in the economic field are countless. In the field of advertising, for example, it has given rise to what is called Neuromarketing. Traditionally, to determine consumer preferences, Marketing used tools such as surveys, questionnaires, interviews, market research, etc. All of these provide information based on conscious consumer behavior, while Neuromarketing seeks to determine the unconscious decision-making process. According to Zaltman (2004), 80% of decisions in the business field are subconscious, "Therefore, we are not aware ofwhy do we do a lot of the things we do because we really feel bad of what we think and most of our decisions acquire characteristics and feelings, emotional rather than logical sense. This is why emotion plays a crucial role in decision-making" (Álvarez del Blanco, 2011, p. 75, our translation).

Hence the importance of Neuroscience applied to the field of Economics, because it allows for a more reliable analysis of people's behavior, facilitating the identification of preferences and influencing decision-making more effectively. Neuroeconomic resources can, for example, be used to foster entrepreneurship through public campaigns or training courses, helping people to strengthen self-confidence and overcome psychological barriers, such as fear of failure or risk aversion.

However, it is important to note that the use of these neuroeconomic resources can also jeopardize neurorights, insofar as neurotechnological devices and procedures could access, alter, manipulate, incorporate, and delete neural data, impacting neural freedom, integrity, privacy, identity, and equality (Lopes, 2022). This same concern was also raised by UNESCO in the Preliminary draft report of the IBC on ethical issues of neurotechnology, prepared in Paris in 2020:

> 116. The development of neuroscience and neurotechnology has made its presence felt in Law. Firstly, neurotechnology, as neuroscience in general does, opens new dilemmas for human rights and specifically for right to freedom of thoughts because the development of new technologies will make them able to access and read the individual thoughts, as we have explained before. It is thus challenging the basic assumptions of inalienable mental privacy. Secondly, because neuroscience also opens doubts about the proper legal concept of free will and, therefore, of legal responsibility and liability. If free will is not truth, it is a merely or not more than human creation without any scientific foundation, and it is not more than a human invention without any scientific support, the individual cannot be blamed for his or her actions because he or she is not criminally prosecutable [...] (UNESCO, 2020).

This is a problem that has not yet been sufficiently explored in the legal field, but which in recent years has been gaining ground in academia, even influencing the emergence of some legislative and jurisprudential initiatives aimed at protecting neurorights, as has happened in Chile, where the constitution was reformed (Chile, 2021) and the Supreme Court suspended the commercialization of non-therapeutic neurotechnologies in the Emotiv case (Chile, Supreme Court, 2023). However, the legal regulation of research, manufacture, commercialization, and use of neurotechnologies has not yet reached a minimum level capable of protecting human beings in the face of these advances, which not only bring benefits but also harms that can undermine human dignity.

3. Regulation of neurotechnology companies

Neurorights can be defined as the rights that protect human dignity in the context of advances in Neuroscience and Neurotechnology. There is no consensus in the doctrine on what these would be or on their nature as human rights. In this work, given its essentiality for the protection of human dignity, its nature as a human right is recognized, and five neurorights are identified:

a) neural liberty: protects the ability to make one's own choices without interference or manipulation.

b) neural integrity: protects against unauthorized alteration of brain structure and function.

c) neural privacy: protects against unauthorized access, alteration, extraction, manipulation, imitation, insertion, use, or storage of neurodata.

d) neural identity: guarantees the continuity of a person's self-concept.

e) neural equality: guarantees the availability of neuroscientific innovations to all.

The development of the concept of neurorights is recent, being attributed to authors such as Ienca and Andorno (2017) who launched their proposal in the paper "Towards new human rights in the age of neuroscience and neurotechnology", published in 2017; as well as Yuste, Genser and Herrmann (2021), who, in 2021, published the paper "It's Time for Neuro-Rights: new human rights for the age of neurotechnology".

Considering that this is a recent topic, the legal regulation of these rights is incipient, with Chile standing out, as previously mentioned, for being the first country in the world to incorporate an express norm for the protection of neuro-rights into its Constitution (Chile 2021). Chile also stands out because its Supreme Court was the first in the world, at this level of jurisdiction, to judge a case involving the protection of neuro-rights. This is the Emotiv case, concerning the use of a neuromodulation device called Insight (Chile, 2023).

In addition to these initiatives, international organizations have already approved documents establishing ethical and legal parameters on the use of neurotechnologies (Lopes, 2025). The first was the "Council Recommendation on Responsible Innovation in Neurotechnology" approved by the Organization for Economic Cooperation and Development (OECD) on December 11, 2019. The second was the "IBC Preliminary Report on Ethical Issues in Neurotechnology" approved by the International Bioethics Committee (IBC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) on December 15, 2020. The third was a document entitled "Possible Impacts, Opportunities and Challenges of Emerging New Digital Technologies with Regard to the Promotion and Protection of Human Rights" approved by the Advisory Committee of the UN Human Rights Council on May 19, 2021. At the regional level, three documents from the Americas stand out: the "Declaration of the Inter-American Juridical Committee on Neuroscience, Neurotechnology and Human Rights: New Legal Challenges for the Americas" approved by the Inter-American Juridical Committee of the Organization of American States (IJC/OAS) on August 11. In 2021, the "Inter-American Declaration of Principles

on Neuroscience, Neurotechnologies and Human Health" was also approved by the IJC/OAS on March 9, 2023. The following month, the Latin American and Caribbean Parliament (Parlatino) approved the "Model Law on Neurorights for Latin America and the Caribbean".

The most recent initiative at the international level is from UNESCO, which, in April 2024, created an Ad Hoc Expert Group (AHEC) to draft a preliminary text of the "Recommendation on Ethics in Neurotechnology," the final draft of which was approved on November 9, 2025 (UNESCO, 2025).

In all these international documents, concern about the responsibility of neurotechnology companies for potential human rights violations is present, although all these documents lack binding force, being classified as soft law (Lopes, 2025).

The establishment of binding legal documents (hard law) to regulate the activities of companies, not just neurotechnology companies, is one of the most critical issues in law. This is a challenge that dates back to the very process of globalization.

The first initiatives came from the UN and the International Labour Organization (ILO) upon realizing that many transnational companies had achieved a level of political and economic power greater than many countries.

> It has rightly been observed that the study of politics in most of the twentieth century has been 'colonized' by the state. What this means is that the subject has been so limited that at its broadest political theory concerned only states as political organisms, while in empirical research and teaching attention concentrated on comparative analysis of states – or even more narrowly (as in American politics) on the political institutions and issues of one particular state. One way or another, the state has come to dominate the subject so that almost everything else has been crowded out. Labor unions, business associations, lobbyists are all studied and their behavior analyzed only insofar as they affect the functioning of the state (Strange, 2009, p. 32).

They also found that transnational business activities had as much impact on the international stage as states, including as a result of actions stemming from irregular conduct and transgressions of customs, norms, and even human rights, but that, despite this, they did not receive the same attention as violations committed by states.

> throughout the past half century, states and international organizations have continued to expand the codification of international human rights law protecting the rights of individuals against governmental violations [...]. the creators of this ever-larger web of human rights obligations, however, failed to pay sufficient attention to some of the most powerful nonstate actors in the world, that is, transnational corporations and other business enterprises. with power should come responsibility, and international human rights law needs to focus adequately on these extremely potent international nonstate actors (Weissbrodt; Kruger, 2003, p. 901).

Given the international political and economic power of transnational corporations and the potentially harmful effects of their activities, some international organizations began, starting in the 1970s, to focus their attention on regulating these activities.

A significant moment in this process occurred in 2005, when Professor John Ruggie of Harvard University was appointed by Kofi Annan, then Secretary-General of the UN, as Special Representative to prepare a report on corporate responsibility standards; the role of States in the process of regulating the obligations of transnational corporations and other business entities; the clarification of the concepts of "complicity" and "sphere of influence""and their implications for companies; the development of materials and a methodology to assess the impact of business

activity on human rights; and the preparation of a compendium on best practices of States and business entities (UN, 2005).

Ruggie served two three-year terms. The first was from 2005 to 2008, at the end of which the report entitled "UN Conceptual Framework to Protect, Respect and Remedy on Business and Human Rights" was published (UN, 2008). The second mandate was between 2009 and 2011, culminating in the publication of the report "Guiding Principles on Business and Human Rights", aimed at implementing and operationalizing the Conceptual Framework.

The report on the "Conceptual Framework to Protect, Respect and Remedy" has the merit of directly establishing obligations for both States and companies, being the main document of the international normative body referring to business entities, highlighting parameters for business activities. The document is based on three basic pillars: a) the State's obligation to protect human beings from violations by third parties, especially business entities; b) the obligation of corporations to respect recognized human rights, that is, to refrain from violating the values of human dignity, in addition to respecting the concept of "due diligence"; and, c) access to reparation mechanisms, directed both to States and to businesses (Ruggie, 2008).

According to this 2008 Report, the state obligation to protect is understood by international law as the duty of States to protect human rights from abuses committed by non-state third parties, including companies. To this end, the Conceptual Framework recommends, as a first pillar, that States take all necessary measures to protect human rights, especially by preventing, investigating and punishing abuses committed, promoting access to means of reparation. To this end, States would have some discretion to choose which measures to take, and such measures should cover all types of business activity.

Regarding the second pillar, that is, the obligation of business corporations to respect human rights, the Report warns that this is not a document of mandatory legal duties, endowed with full enforceability, but rather an instrument of soft law. In effect, this pillar aims to ensure that business activities are not synonymous with violations of recognized human rights. In this sense, the concept of "due diligence" in human rights matters emerges, understood as "a process whereby companies not only ensure compliance with national laws but also manage the risk of human rights harm with a view to avoiding that" (Ruggie, 2008, p. 194).

The third pillar refers to access to means of redress. In fact, without mechanisms for investigation, punishment, and compensation, the effects of the States' obligations to protect human rights from corporate abuses would be almost useless.

Having established the three pillars relating to the relationship between companies and human rights, the next step would be to put them into practice. Thus, on June 18, 2008, the Human Rights Council adopted the pillars set forth in this Report, recognizing the need to operationalize them in order to enable more effective protection against human rights abuses perpetrated by transnational corporations or other businesses, and to contribute to the consolidation of norms and parameters related to business activity (UN, 2008).

From this perspective, compiling all the work carried out between 2005 and 2011, John Ruggie presented in March 2011 a final report entitled "UN Guiding

Principles on Business and Human Rights", known as the Ruggie Report, aiming to implement and detail the Conceptual Framework developed in 2008. It can be said that

> The Guiding Principles' normative contribution was in elaborating the implications of existing standards and practices for States and businesses; integrating them within a single, coherent and comprehensive template; and identifying where the current regime fell short and how it should be improved (ONU, 2011, p. 716).

In the same year, the Human Rights Council welcomed the Ruggie Report, establishing a Working Group for the dissemination and implementation of the document, tasked with delivering an annual report on the work carried out to the Council. Furthermore, a Forum on Business and Human Rights was established, under the auspices of the Working Group, to discuss the challenges in implementing this 2011 Report and to promote international cooperation on issues related to business and human rights (UN, 2011).

The Ruggie Report is structured around an introduction, which includes the general guiding principles for regulating the interaction between business and human rights, among which the provision that the provisions apply to all States and all companies, regardless of any factor, stands out, as well as the provision that the Principles should not be interpreted in a way that establishes new obligations under international law, nor in a way that restricts or reduces the duties assumed by States (UN, 2011).

The document is divided according to the three pillars of the 2008 Conceptual Framework, aiming to detail and implement, compartmentalizing the principles relating to each of these pillars, giving special attention to situations where there is a link between the State and companies, either because these are entities that are part of the state structure, even if with their own legal personality or private law, or because they receive high monetary incentives from the State. In effect, Principle 4 requires States to adopt additional measures in the aforementioned situations, requiring, if necessary, audits on human rights matters. In practice, because the document is not binding, little has been effectively implemented.

In view of this, the Human Rights Council, through Resolution No. 26/09, established the "Open-ended Intergovernmental Working Group on Transnational Corporations and Other Business Enterprises with Respect for Human Rights", whose acronym in English is OEIGWG, with the objective of developing a legally binding international instrument. This Group has already approved three drafts of the Treaty: Zero Draft, dated July 16, 2018; Draft 1, dated July 16, 2019; Draft 2, dated August 6, 2020; and Draft 3, dated August 17, 2021 (UN, 2024). The most recent session of the OEIGWG was the 11th, held in Geneva from October 20 to 24, 2025, which focused on articles 12 to 24, relating to corporate accountability for human rights violations. The prospects for the Treaty's approval remain pessimistic, highlighting a slow and complex process of advances and setbacks.

Although there is still no legally binding document on corporate responsibility for human rights violations, the two reports by John Ruggie, 2008 and 2011, have served as a reference for the drafting of other international and national documents. Thus, regarding the regulation of neurotechnology companies, the documents already

approved by the OECD, UN, OAS and Parlatino, mentioned above, base part of their texts on the pillars: protect, respect and repair.

However, in the most recent international document on the subject, the "Draft Recommendation on the Ethics of Neurotechnology", approved by UNESCO in November 2025, the mention of the concept of due diligence, adopted in the Ruggie Report of 2008, stands out, although only with a recommendatory and not mandatory character.

> 55. All actors in the whole life cycle of neurotechnology should adhere to ethical principles in order to prevent, anticipate and address potential harms – whether short-term, long-term or arising from unintended use and impact. They should commit to taking due diligence steps to identify, prevent, mitigate and account for how they address and redress any adverse impacts. They should also commit to adjusting practices in response to new evidence or ethical concerns, to remain open to feedback and to clear and transparent communication (Unesco, 2025).

In contrast, the European Parliament and the Council of Europe approved Directive 2024/1760 on sustainability and human rights on June 13, 2024. This document represents a significant step forward by expressly establishing the obligation for companies to "avoid violating human rights and addressing adverse effects on these rights that have been caused, to which they have contributed or are linked to their own operations, their subsidiaries and their direct and indirect commercial relationships" (European Parliament and Council of Europe, 2024, our translation). This is a noteworthy advancement because it makes mandatory what was previously voluntary, signaling a positive future.

However, authors such as Tole Martínez and Rosero Huertas (2022) focus more on the precautionary principle than on the principle of due diligence in the field of Neurotechnology, considering the high degree of uncertainty about the effects of advances in this area. It should be noted that due diligence involves a continuous process of managing known or potential risks, focusing on preventing and mitigating harm, while the precautionary principle acts in the face of scientific uncertainty, prohibiting or limiting certain activities.

> Although neuroscience is a field of application that does not yet have exact science, the damages that could generate in neuronal activity and data commercialization, include the precautionary principle within protection standards such as the OAS Declaration, it becomes a matter of special consideration for future debates within the organization (Tole Martínez and Rosero Huertas, 2022, p.130-131, our translation).

The precautionary principle is not new. Its discussion dates back to the 1960s and 1970s within the framework of debates on the global environmental crisis, and it was expressly adopted in the Rio Declaration on Environment and Development of 1992.

> Principle 15
>
> In order to protect the environment, the precautionary principle should be widely observed by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation (UN, 1992, our translation).

The scope and consequences of neuro-techno-scientific advances are unpredictable, and the speed at which they occur conspires against any more accurate regulation. In this context, the duty to act with due diligence, or better yet, with precaution, presents itself not as a magic solution, but as a warning about the need for self-limitation when the uncertainties of the effects of these advances make a point of no return seem apparent.

Conclusion

Neuroeconomics constitutes a new area of knowledge that emerged from the interface between Neuroscience, Neurotechnology, Artificial Intelligence, and Economics, revolutionizing the way we understand brain reactions at the moment of decision-making in the economic field. This quality of Neuroeconomics can be used to promote the skills necessary to be a good entrepreneur, thus contributing to economic development and the reduction of social inequalities, by combating unemployment and fostering innovative and dynamic business environments.

There is no doubt, therefore, about the benefits of Neuroeconomics; however, alongside these benefits, there are also drawbacks, since neurotechnologies also could access, alter, manipulate, insert, and delete neural data, jeopardizing neurorights to liberty, integrity, privacy, identity, and neural equality.

Although Neuroeconomics is already being used in much of the world, including Brazil, there are no binding international (hard law) or national norms aimed at regulating the activity of companies that research, produce, market, and use neurotechnologies, highlighting the existence of a legal vacuum that exacerbates the vulnerability of users of these advances.

In this context, documents such as the reports entitled "Conceptual Framework for Protecting, Respecting and Repairing" and the "Guiding Principles on Business and Human Rights," prepared by John Ruggie, UN Special Representative, and published in 2008 and 2011, respectively, continue to be a reference when preparing other documents at both the international and national levels, especially for introducing principles such as due diligence, which seeks to prevent and mitigate harm to human rights, and which was adopted by UNESCO in its most recent draft Recommendation on the Ethics of Neurotechnology, approved in 2025.

However, given a landscape riddled with numerous scientific uncertainties, it may be more prudent to embrace the precautionary principle, which, instead of merely seeking to prevent and mitigate harm, aims to avoid it by prohibiting actions whose effects are unknown but potentially serious and irreversible, as is the case with many current neuroscientific advances, which put humanity itself at risk.

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Protecting the mind in the age of neurotechnologies: Spain faces the challenge of neuro-rights

MARÍA CONCEPCIÓN RAYÓN BALLESTEROS[1]

Introduction

The rapid development of neurotechnologies over the last decade has ushered in an unprecedented era in the relationship between humans and technology. For the first time, it is technically possible to record, interpret and even modulate people's brain activity using invasive or non-invasive devices, for purposes ranging from neurological rehabilitation and disease treatment to cognitive enhancement. This ability to interact with the most intimate sphere of the individual—their mind—constitutes one of the most profound legal and ethical challenges of the 21st century. In Spain, the creation in December 2024 of the National Centre for Neurotechnology (Spain Neurotech) marks an institutional milestone that places Spain at the forefront of international science but also accelerates the urgency of defining a regulatory framework capable of guaranteeing the dignity and fundamental rights of individuals in the face of these new technological scenarios.

[1] Professor of Law at the Complutense University of Madrid (Spain). Lawyer of the Bar Association of Madrid. Mediator registered with the Ministry of Justice. PhD in Law and Licentiate in Political Science and Administration. mariaconcepcionrayon@gmail.com

Unlike other technological revolutions, neurotechnology does not only affect data about the person or their observable behaviours; it directly affects the neurophysiological processes that underpin thought, personal identity, emotions and will. As Marcello Ienca and Roberto Andorno (Ienca and Andorno, 2017), pioneers in the formulation of the concept of *neurorights*, have pointed out, brain activity constitutes "the natural frontier of human privacy," and intervention in it poses risks that traditional legal frameworks have not been designed to address. The proposal of these authors, later taken up by Rafael Yuste and the so-called *Morningside Group (*Yuste *et al.,* 2017), advocates recognising a set of emerging rights -cognitive freedom, mental privacy, mental integrity, psychological continuity, and equitable access to neurotechnology- as a structural response to the challenges of this new era.

In Spain, the issue is particularly relevant because the legal system does not explicitly recognise mental privacy or cognitive integrity, even though some constitutional provisions provide a solid basis for interpretation: dignity and free development of personality (Art. 10 CE), privacy and secrecy of communications (art. 18 CE), and physical and moral integrity (art. 15 CE). However, the very nature of neurodata, defined as information derived from the nervous system capable of revealing inferences about thoughts, emotions or mental states, forces us to reconsider whether current instruments, particularly the GDPR and the LOPDGDD, are sufficient to guarantee the protection of this sphere. As warned in the *TechDispatch* report by the European Data Protection Supervisor (EDPS, 2024), the processing of neurodata constitutes "an unprecedented risk to privacy and mental autonomy", insofar as it allows for non-consensual inferences of unparalleled depth.

This regulatory concern has begun to be reflected in Spanish legislation. The Draft Digital Health Bill of Cantabria (2025) is the first European text to expressly incorporate a regulation of neuro-rights, recognising neurodata as a specially protected category and establishing specific guarantees against the non-consensual manipulation of cognitive or emotional processes. Although this is a regional initiative, its very existence anticipates an inevitable debate: the possible regulatory fragmentation between autonomous communities in an area that, by its very nature, demands a comprehensive and coordinated response at the state and European level.

At the same time, European institutions have begun to warn of the geopolitical and democratic impact of these technologies. The 2023 León Declaration, approved by EU telecommunications ministers, warns that the manipulation or misuse of neurodata "could influence people's thoughts and behaviours, open the door to new cyberattack mechanisms and pose a threat to fundamental rights and European democracies". These warnings highlight that neurotechnology does not only affect the biomedical field but is a cross-cutting phenomenon that affects constitutional law, criminal law, civil law, procedural law, data protection and public ethics.

All of this justifies the need for a systematic legal analysis to assess the current state of Spanish law, identify regulatory gaps and propose appropriate protection mechanisms for a scenario in which the human mind -until now the last inviolable bastion of privacy- may become a technologically accessible space.

This article aims to examine the Spanish and European context, systematise the main doctrinal and institutional proposals, and offer a reasoned proposal for the legal construction of neuro-rights, with special reference to mental privacy and neurodata

protection. Through a methodology that combines normative, doctrinal and comparative analysis, it aims to contribute to a debate that will be decisive in shaping the model of fundamental rights for the coming decades throughout the world.

1. Neurotechnologies in Spain: scientific advances and legal challenges

The development of neurotechnologies has moved beyond the strictly experimental realm to become a strategic pillar of biomedical and technological innovation on a global scale. Spain has embraced this transformation wholeheartedly, promoting initiatives of great institutional and scientific relevance which, however, are advancing faster than the ability of the law to provide a coherent regulatory framework. Neurotechnology is a multidisciplinary field that encompasses devices, techniques and systems capable of recording, interpreting or modulating neuronal activity, either through invasive procedures –such as intracortical implants[2]– or through non-invasive interfaces, such as systems based on EEG,[3] fNIRS[4] or transcranial magnetic stimulation. In all cases, the characteristic feature is direct interaction with the central or peripheral nervous system, which differentiates this field from other emerging technologies and justifies the special attention that legal systems are beginning to pay to advances in neurotechnologies.

1.1. Concept, nature and scope of neurotechnologies

From a biomedical point of view, neurotechnologies are defined as the set of tools that allow access to, monitoring or intervention in neuronal activity for diagnostic, therapeutic, research or cognitive enhancement purposes. This last dimension -non-therapeutic enhancement- is one of the most intense ethical debates, as it raises questions about equity, personal autonomy and the limits of intervention on psychological identity. The truth is that, by allowing not only *the reading* of information from the brain, but also *the writing* or *modulation of* certain processes, these technologies introduce a level of complexity that is and exceeds the traditional framework of medical devices regulated in the European Union.

The novelty of these capabilities requires a rethinking of fundamental legal concepts such as consent, dignity, personal integrity and responsibility. Unlike other forms of data processing, brain information is not voluntary, nor is it completely controllable by the individual, which increases the person's vulnerability to possible unauthorised interventions or access.

1.2. Spain as an emerging player: the National Centre for Neurotechnology (Spain Neurotech)

Spain occupies a prominent position in the consolidation of a scientific infrastructure geared towards the study and application of neurotechnologies. The creation

[2] Intracortical implants are electronic devices surgically implanted into brain tissue to record or stimulate the activity of individual neurons or groups of neurons.

[3] EEG (electroencephalogram) is a non-invasive technique that measures the electrical activity of the brain by placing electrodes on the scalp.

[4] Functional near-infrared spectroscopy (fNIRS) is a non-invasive technique used to measure brain activity by detecting changes in the absorption of near-infrared light by brain tissue.

in December 2024 of the National Neurotechnology Centre (Spain Neurotech) is an unprecedented strategic milestone in the European landscape. It is one of the world's leading centers specializing in advanced neurotechnology.[5] The Spanish centre is the result of collaboration between the Spanish Government, the Community of Madrid and the Autonomous University of Madrid.

The centre pursues far-reaching scientific, health, economic and ethical-legal objectives, such as the following:

a) deepening our understanding of the human brain.

b) to develop new diagnostic methods and therapies for neurological diseases.

c) promoting innovation and technological entrepreneurship.

d) promoting the training of new generations of researchers.

e) developing ethical and legal standards for research and use of these technologies.

f) involve society in the public debate on neurotechnology and human rights.

The promotion of this institution reflects a national commitment to placing Spain at the forefront of science and technology, but at the same time highlights the urgent need for a legal framework capable of anticipating the risks associated with the use of these tools.

1.3. Clinical applications and biomedical projection: opportunities and main legal challenges

In the field of healthcare, neurotechnologies offer possibilities that were previously unthinkable. Their applications include the treatment of autism spectrum disorders, Parkinson's disease, Alzheimer's disease, resistant depression, sleep disorders, epilepsy and spinal cord injuries, as well as rehabilitation after brain damage. The combination of brain-computer interfaces (BCI)[6] and artificial intelligence enables the recovery of motor or communication functions in patients with severe neurological problems. These innovations make neurotechnologies an indispensable tool for the future of personalised medicine.

Spain is at the forefront of the clinical application of neurotechnologies, with a public and private hospital network that has progressively integrated techniques such

[5] Centers specializing in advanced neurotechnology worldwide include renowned institutions in the United States, Europe and Asia, which are renowned for their research into brain-machine interfaces, neuroprosthetics, neuromodulation and advanced neuroimaging. In the United States, institutions such as the MIT Centre for Bionics, the University of Washington Centre for Neurotechnology, and the Columbia University Centre for Neurotechnology are leaders in the development of BCIs, neuroengineering, and neurological devices, in addition to prominent clinical centers such as the Cleveland Clinic and Mayo Clinic in applied neurotechnology (,). In Europe, the NeurotechEU network, which includes universities such as Radboud, Oxford, and the Max Planck Institute, focuses on neurotechnology and the brain, along with institutes such as the Forschungszentrum Jülich in Germany, which specializes in neuroimaging and computational models of the brain (webIn Asia, institutions such as i-BRAIN in China, which works on implantable BCIs, and universities such as Tokyo and Fudan, stand out for their advances in neurotechnology, neuroimaging and neuro-AI (). Other notable international centers include the Picower Institute at MIT, the Weill Institute at UCSF, and the Montreal Neurological Institute, which lead research in neurotechnology in both academia and clinical and business applications, frequently collaborating on international projects.

[6] The combination of brain-computer interfaces (BCI) consists of systems that establish direct communication between the human brain and external devices, such as computers or prostheses, without the need to activate peripheral nerve pathways or muscles. These interfaces enable the translation of electrical signals from the brain into commands that can be understood and acted upon by machines, facilitating everything from the rehabilitation of lost functions to the enhancement of human capabilities or communication in people with motor disabilities.

as deep brain stimulation (DBS), focused ultrasound (HIFU), brain-computer interfaces (BCI), transcranial magnetic stimulation (TMS), intracranial laser ablation and robotic neuroprostheses. These technologies, initially reserved for research contexts, have rapidly moved into the clinical sphere, generating tangible improvements in the treatment of complex neurological diseases such as Parkinson's, refractory epilepsy, resistant psychiatric disorders, spinal cord injuries and childhood dystonias.

Hospitals such as La Princesa, Vall d'Hebron, Bellvitge and La Fe have developed advanced surgical programmes for neurostimulation and minimally invasive procedures, demonstrating their commitment to high-impact medical innovation. At the same time, centres such as the National Hospital for Paraplegics and the Institut Guttmann have promoted the application of neurotechnologies in the field of rehabilitation, especially for patients with severe neurological damage, through robotics, non-invasive brain stimulation, virtual reality and adapted BCIs. The University of Navarra Clinic and the Sant Joan de Déu Hospital, for their part, have shown how neurotechnology can be integrated into highly specialised treatments, including gene therapies, paediatric bionic devices and high-precision image-guided procedures.

However, this therapeutic potential coexists with significant risks. Intervention in neural processes can cause irreversible damage, affect essential cognitive functions or produce adverse effects that compromise the physical or mental integrity of the patient.[7] From a legal point of view, this requires strengthening ethical evaluation mechanisms, clinical trials, safety standards and, above all, informed consent requirements, which must incorporate specific information on neurological risks, scientific uncertainties and neurodata processing.

The first legal tension arises around informed consent. Given the complexity of these technologies and the difficulty of predicting all their neurological effects, a reinforced consent model that goes beyond traditional biomedical logic is required. This consent must address not only the physical intervention, but also the access, processing and interpretation of the neurodata generated by the device.

The second challenge relates to civil and criminal liability for possible neurological damage. Manipulation of the nervous system raises the need to review the criteria of causality, foreseeability and inherent risk, especially in cases of irreparable effects or alteration of personality, memory or identity. The attribution of liability can be complex when multiple actors are involved: designers, manufacturers, medical teams, research centres or artificial intelligence systems associated with the device.

The third challenge directly affects the core of human dignity. The possibility of influencing cognitive processes, modifying behaviour or inferring mental information without consent raises strict ethical limits that the law must guarantee. Dignity, understood as moral autonomy and free development of personality, thus becomes the central axis for designing any regulation on neurotechnology.

Finally, there is the challenge of equity: unequal access to technologies that enhance cognitive abilities could deepen existing social divides, creating what some authors call "neurotechnological stratification" (Ienca, 2921). The law must ensure that innovation does not compromise real equality or generate new forms of cognitive discrimination.

[7] On clinical risks, see also OECD, Recommendation on Responsible Innovation in Neurotechnology, 2019.

2. Neurodata: a new challenge for personal data protection

As has been highlighted throughout this paper, the expansion of neurotechnologies has led to the emergence of a new type of extremely sensitive information: neurodata. Unlike other traditional categories of biometric data, such as fingerprints or facial recognition, neurodata is radically different in nature, as it is derived from brain activity and can reveal inferences about thoughts, emotions, behaviour patterns, cognitive preferences or even mental health states. This uniqueness has led European and national institutions to classify neurodata as one of the most sensitive categories of information in the digital age, with characteristics that go beyond the current legal framework for data protection.

2.1. Concept and typology of neurodata

Neurodata can be defined as *any information obtained directly or indirectly from the central or peripheral nervous system*, including both raw data (electrical signals, action potentials, neurophysiological patterns) and derived inferences generated by artificial intelligence systems. This definition, found in specialist literature and institutional reports such as the *TechDispatch* of the European Data Protection Supervisor (EDPS), highlights the hybrid and highly interpretative nature of this information: it is not limited to measuring neuronal activity, but also allows elements of an individual's inner life to be deduced.

TechDispatch classifies neurodata according to two main criteria: the type of information recorded and the purpose of the processing.

a) Types of neurodata according to their biological origin:

Structural data: relating to brain anatomy (e.g., MRI-type neuroimaging).[8]

Functional data: neural signals, electrical activity (EEG), haemodynamics (fMRI), blood flow or connectivity patterns.[9]

Peripheral nervous system data: muscle, nerve or sensory activity recorded through human-machine interfaces.[10]

b) Types of neurodata according to the purpose of processing:

Category 1: inference and cognitive analysis data, used to deduce mental states, attention, emotions or personality[11] traits, that can be used for applications: education, neuromarketing, security.

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[8] Brain tissue is mainly composed of cells called neurons and supporting cells (glial cells), as well as the spaces between them that allow for the exchange of substances. Techniques such as histology and microscopy allow us to observe the structure of these cells, their shapes, and how they physically relate to each other, which helps us understand their organization and functioning at a microscopic level.

[9] o study how the brain works, techniques such as neuroimaging (e.g., functional magnetic resonance imaging) and neurorecording (e.g., electroencephalogram) are used. These techniques allow researchers to record the electrical activity of neurons or blood flow in different areas of the brain, as active areas consume more oxygen and generate detectable signals, revealing how regions such as the brain stem, cerebellum, or brainstem work during different functions.

[10] Data from the peripheral nervous system is collected using devices called peripheral nerve interfaces (PNIs), which incorporate electrodes to capture the bioelectrical activity of the nerves. These devices can be placed inside the nerve, on its surface or near it, and allow the anatomy, function and activity of peripheral nerves to be analyzed, facilitating the study of how information is transmitted from the brain to the rest of the body.

[11] Neurodata processing involves analyzing brain activity and function to obtain direct information or predict aspects such as physical health, problem solving, reasoning, memory, emotions or language. Thanks to artificial intelligence, brain signals can be decoded to interpret thoughts, such as converting the imagination of writing into text, or inferring emotions. Extreme neuroanalysis techniques are also being explored, such as 'brain fingerprinting' to identify individuals or detect recognition and lies using specific brain waves. However, the scientific validity of these

Category 2: data for device control, used in brain-computer interfaces (BCI) to control prostheses, wheelchairs or video games through neural activity.[12]

Category 3: data for neural stimulation or modulation, intended for therapeutic or cognitive enhancement interventions (neurofeedback, electrical/magnetic stimulation).[13]

This classification reveals that neurodata is not homogeneous, and that some types pose significantly greater risks to privacy and mental integrity than others.

2.2. Insufficient regulation of the General Data Protection Regulation and the Organic Law on Personal Data Protection and Guarantee of Digital Rights

Current European legislation on personal data protection, consisting of the General Data Protection Regulation (GDPR) and Organic Law 3/2018 on Personal Data Protection and Guarantee of Digital Rights (LOPDGDD), has significant limitations in the face of the challenges posed by the processing of neurodata. Despite the extreme sensitivity of this type of information—capable of revealing mental and emotional states or even unspoken intentions—neurodata has not been recognised as a separate category within current legislation. Both regulatory instruments are limited to regulating categories such as health data or biometric data, which, although they share certain characteristics with neurodata, do not fully capture its complexity or associated risks.

Although the GDPR establishes general principles that are formally applicable to the processing of any personal data – such as proportionality, minimization, accuracy, transparency, and fairness- these are clearly insufficient to regulate the specific scenarios arising from the use of neurotechnologies. As pointed out by the European Data Protection Supervisor (EDPS), neurodata presents unprecedented risks not contemplated by European legislators, including: the involuntary and uncontrolled generation of neural data; the ability of artificial intelligence systems to infer highly sensitive information from brain patterns; and the technical difficulty of ensuring anonymisation or pseudonymisation, due to the uniqueness and irreproducibility of each individual's "brain fingerprint".

Along the same lines, the Spanish Data Protection Agency (AEPD) has identified neurodata as one of the main regulatory challenges of the immediate future. In its Strategic Plan 2025–2030, the AEPD stresses the urgent need to establish specific technical and h s criteria, as well as to strengthen institutional supervision and

applications, especially for lie detectors and emotional recognition by AI, has not been proven and may pose risks to fundamental rights.

[12] Brain-computer interfaces (BCIs) allow devices and applications to be controlled by reading brain signals, not only interpreting them, but also using them to direct those machines. In other words, in addition to obtaining information from the brain, these technologies can send commands to control external devices such as prostheses, robots, or virtual reality systems. Some examples include orthopedic and prosthetic aids, video games, robotics, and defense applications, in which brain activity is translated into movements or commands to operate these devices without the use of hands.

[13] Neurodata processing through neurofeedback involves using a person's brain signals to generate feedback that returns to the brain itself, forming a cycle of stimulus and response. This allows the person to learn to regulate their brain activity, even without being aware of it. In psychology, neurofeedback is used as a therapy to treat disorders such as ADHD, anxiety, depression, epilepsy, or insomnia by showing the patient visual or auditory signals that reflect their brain activity, helping them to modify it. In addition, this technique can improve cognitive and emotional abilities in healthy people, promoting better brain performance. Neurofeedback is a non-invasive therapy based on training and brain plasticity that generates lasting changes in brain function through self-regulation.

control mechanisms, given the sensitivity of brain processing and its potential impact on fundamental rights.

This diagnosis has led sectors of national and international doctrine to question whether neurodata should be subject to specific enhanced protection, as is the case with genetic data, or whether, failing that, it should inspire the recognition of a new autonomous right to mental privacy, guaranteeing the inviolability of neurocognitive processes against any form of intrusion or misuse.

The TechDispatch report referred to earlier in this study, published by the EDPS, represents the most rigorous systematisation of the state of the art to date. It highlights the need to: establish mandatory human oversight mechanisms for all automated processing of neurodata; ensure algorithmic transparency and explainability; apply strict data minimisation models, limiting neural collection to what is strictly necessary; and conduct comprehensive impact assessments on fundamental rights and mental health before authorising any technological application based on neuroinformation.

In short, both national and European authorities agree that the current regulatory framework is insufficient to adequately respond to the challenges posed by the development of neurotechnologies. The integration of neurodata into the European legal system, either through its recognition as a special category or through the formulation of new emerging digital rights, is an urgent regulatory necessity in the context of the future regulation of neurorights.

2.3. Specific legal and ethical risks associated with the use of neurodata

The processing of neurodata poses unprecedented threats to fundamental rights, far greater than those posed by other digital technologies. Among the most significant risks are:

a) Extreme intrusion into the mental sphere: through the analysis of neural patterns, it is possible to infer emotions, preferences and even automatic cognitive responses without the individual's knowledge (Ienca and Andorno, 2017). This can translate into sophisticated forms of psychological surveillance.

b) Erroneous or biased inferences: AI systems used to interpret neurodata can generate incorrect or discriminatory conclusions, especially in clinical, educational or work contexts.

c) Risks to mental integrity: certain interventions increase the risk of altering essential cognitive processes (memory, attention, identity), compromising the person's psychological *continuum*.

d) Discrimination and commercial exploitation: intensive neuromarketing, cognitive monitoring at work or the analysis of mental performance in education raise scenarios of emotional exploitation and inequality.

e) Vulnerability to cyberattacks: neurodata can be manipulated or stolen, giving rise to what some experts call *neuro-hacking*.

The 2023 León Declaration on European Neurotechnology: A Human Rights-Based, Person-Centred Approach warns that the manipulation of brain data could be used to influence human behaviour, creating risks that justify the need for a strengthened and specific legal framework.

2.4. Towards a new legal paradigm: the need for a right to mental privacy

The inadequacy of the current framework and the exceptional sensitivity of neurodata have led legal scholars to propose the autonomous creation of a right to mental privacy, understood as an inviolable sphere of inner freedom from the non-consensual collection, analysis or manipulation of brain information.

This right would not replace privacy or data protection but would act as a reinforced guarantee against technologies capable of penetrating the mental sphere. The express recognition of this right would make it possible to define clear limits on the processing of neurodata; reinforce informed consent; penalise cognitive manipulation; ensure the transparency and traceability of neurotechnological algorithms; and protect dignity, autonomy and personal identity.

3. Neuro-rights in the spanish legal framework

The emergence of neurotechnologies and the growing ability to record and infer mental processes have led to the formulation of a new conceptual category within the field of law: neurorights. Although the term is relatively recent -its first systematic use dates to 2017- its doctrinal and political impact has been remarkable, to the point of becoming one of the most relevant proposals for redefining fundamental rights in the 21st century.

The majority doctrine agrees that neurorights arise from the recognition of a structural inadequacy of the traditional legal framework to protect what constitutes the very essence of the person: their mental sphere, psychological identity, freedom of thought and the continuity of their own subjectivity. The digitisation of the brain, i.e. the ability to transform neural processes into quantifiable data, requires new guarantees to accompany this scientific revolution without compromising human dignity.

3.1. Origin of the term neuro-rights and their initial formulation

Neuro-rights were initially formulated by **Marcello Ienca** and **Roberto Andorno**, who in 2017 proposed recognising a new category of human rights specifically aimed at protecting brain activity as a central manifestation of personal autonomy. Their proposal included four emerging rights: cognitive freedom, mental privacy, mental integrity and psychological continuity.

Shortly afterwards, the concept was expanded by Rafael Yuste, a neuroscientist at Columbia University, and by the so-called Morningside Group, made up of experts from disciplines such as neurotechnology, ethics, law and artificial intelligence, belonging to academic and technological institutions in the United States, Canada, Europe, Israel, Japan and Australia. The publication of their proposals in *Nature* brought immediate international recognition, placing the issue at the centre of the debate on the ethical limits of technological development.

Previous literature on neuroethics -with antecedents in authors such as Richard Glen Boire, Wyre Sententia, Christoph Bublitz, and Andrea Lavazza- had already raised some of these issues, but without the systematic articulation presented by Ienca, Andorno, and Yuste in 2017. Their contribution consists of conceptualising the

mind as a legal space, susceptible to protection against potentially invasive technological interference.

The main neuro-rights formulated by the doctrine can be summarised as follows:

a) Cognitive freedom: this consists of the individual's ability to freely decide whether or not to allow access, recording or intervention in their brain activity. It includes the rejection of coercive uses and the guarantee of self-determination over one's own mind.

b) Mental privacy: this refers to the right to keep information relating to thoughts, emotions, preferences or mental states out of the reach of third parties, whether public or private. Mental privacy thus transcends the traditional concept of privacy, as it encompasses information that may be generated without the individual's knowledge or control.

c) Mental integrity: linked to physical integrity, but distinct from it, mental integrity protects against all forms of manipulation, damage or non-consensual interference in neural processes. This neuro-right is particularly relevant in the case of interventions that may alter the will, memory or personal identity.

d) Psychological continuity: this involves the preservation of personal identity and the narrative coherence of the individual. Its violation can occur when a neurotechnological intervention generates abrupt changes in personality or in the cognitive processes that underpin self-perception.

e) Equitable access to neurotechnologies: defends the need to avoid structural inequalities in access to tools that can improve cognitive or motor skills, preventing a neurotechnological divide between social groups.

Taken together, all these rights seek to protect the mental sphere as an autonomous legal right, whose relevance is not limited to privacy or physical integrity, but affects the very essence of human dignity.

3.2. Constitutional framework for neurodights in Spain

The Spanish constitutional framework provides a solid basis for neurodiverse rights, although it does not expressly recognise them. Among the relevant provisions are the following:

Article 10 CE: establishes the dignity of the person and the free development of personality as the foundation of political order and social peace.

Article 18 CE: protects personal and family privacy, as well as the secrecy of communications.

Article 15 CE: recognises physical and moral integrity.

However, these constitutional precepts have limitations when it comes to regulating interventions in a person's brain activity. Article 18 of the Spanish Constitution protects against external interference in the private sphere but does not provide for the possibility of mental inferences based on neurodata generated involuntarily. Similarly, the notion of moral integrity in Article 15 of the Spanish Constitution must be reinterpreted to encompass cognitive integrity, which is not limited to the absence of physical harm, but also includes the preservation of identity and essential psychological processes (Garrigues Walker, 2024).

Informational self-determination, recognised in the LOPDGDD, is also insufficient to protect the mental sphere, as it is based on control over voluntarily provided data, and not on automatically generated brain information. For this reason, a growing sector of Spanish doctrine—Garrigues, Ausín, Morte, Monasterio, among others—argues for the need to explicitly recognise an autonomous right to mental privacy or neuroprotection.

3.3. The Charter of Digital Rights: a programmatic approach to neurorights

The Spanish Charter of Digital Rights is the first *soft law* regulatory instrument to include specific guarantees for the use of neurotechnologies. Its section XXVI, dedicated to digital rights in the use of neurotechnologies, establishes principles aimed at protecting the identity, self-determination and confidentiality of brain data.

Its contents include: the prohibition of interventions that affect physical or mental integrity without reinforced guarantees; the obligation to ensure the security and confidentiality of neurodata; the prevention of bias and decisions conditioned by incomplete or manipulated data.

However, the Charter is not binding and is intended as a roadmap for action by public authorities. It has obvious limitations as it is not a law: it does not precisely define which technologies are included, it does not establish supervision mechanisms or sanctions, it does not resolve the liability regime in the event of damage, and it does not address issues such as the portability, anonymisation or interoperability of neurodata. Nevertheless, its symbolic value and guiding role are indisputable, as it constitutes the first institutional recognition of the need for specific legal protection for the human mind.

3.4. Special reference to the Draft Digital Health Law of Cantabria

In Spain, the Draft Digital Health Law of Cantabria (2025) is the first text to expressly recognise that neurodata should receive the same level of protection as the *special categories of data* in the GDPR. Although pioneering, this initiative opens up the debate on the risk of regulatory fragmentation in an area that requires uniform responses.

The draft law analyzed introduces the first comprehensive regulatory approach to neurotechnologies and the protection of neurodights and neurodata in the healthcare field. Firstly, Article 27 defines neurotechnologies as those devices, techniques or systems that interact directly with the nervous system, invasively or non-invasively, for diagnostic, therapeutic, cognitive enhancement or monitoring purposes, thus narrowing down the scope of regulation. Article 28 subjects their use to prior scientific, ethical and clinical evaluation, in accordance with current regulations, making their effective application in patients conditional on a rigorous ex ante assessment of their safety, efficacy and suitability.

Article 29 sets out the core guarantees of the legal regime for neurotechnologies. In its first section, it prohibits any non-consensual manipulation of cognitive or emotional processes and imposes, for any health application, the obligation to

guarantee the individual's control over their identity, self-determination and individual sovereignty in decision-making, the confidentiality and security of data linked to brain activity and processes, as well as the specific regulation of person-machine interfaces that may affect physical or mental integrity, preventing decisions or processes based on neurotechnologies from being conditioned by the provision of data. In its second section, the regulation equates neurodata, within the scope of the Autonomous Health System, with the special categories of data in Regulation (EU) 2016/679 and Organic Law 3/2018, so that the maximum guarantees of protection applicable to particularly sensitive data are applicable to them.

The debate is ongoing in Europe and Spain and is likely to be one of the main topics of discussion in future regulation related to technological advances.

4. European and international context

The regulation of neurotechnologies and the protection of neurodights cannot be understood exclusively from a national perspective. This is a global phenomenon that involves cross-border challenges, both scientific and legal, which require coordinated responses at the international level.

4.1. UNESCO: Recommendation on the Ethics of Neurotechnology (2025)

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) has taken a decisive step in the global governance of neurotechnologies with the adoption, in November 2025, of the Recommendation on the Ethics of Neurotechnology. This is the first binding international instrument in ethical and political terms that focuses specifically on the challenges arising from the interaction between the human nervous system and technology.

The text urges States to establish robust, agile and equitable regulatory frameworks that ensure the protection of brain data, mental privacy and the responsible development of neurotechnology. It recognises the therapeutic potential of these tools, especially in neurology and psychiatry, but warns of their structural risks to human dignity, cognitive autonomy, personal identity and mental integrity.

The Recommendation articulates an ethical framework based on fundamental principles of international human rights law: dignity, freedom of thought, physical and mental integrity, equality and non-discrimination. Additionally, it proposes the creation of national oversight bodies, reinforced cybersecurity standards, algorithmic transparency mechanisms, and accountability systems, especially in the face of harmful uses of technology (e.g., for social control, manipulation, or discrimination).

The document incorporates a cross-cutting approach covering the sectors of health, justice, education, scientific research and artificial intelligence, and stresses that neurotechnology integrated with AI can generate forms of emotional surveillance, cognitive inference and behavioural modulation that require a reinterpretation of existing rights — in particular the right to privacy and non-interference in private life. UNESCO thus positions the inviolability of the mind as a new ethical and legal frontier that requires enhanced protection at the international level.

4.2. European Union (EU)

Although the European Union has not yet adopted specific and binding regulations on neurotechnologies, it has begun to lay interpretative and guiding foundations that may underpin future regulatory harmonisation.

Among the relevant legal texts, the Charter of Fundamental Rights of the EU stands out, whose articles 1 (human dignity), 3 (physical and mental integrity), 7 (private life) and 8 (protection of personal data) provide a legal basis which, although indirect, is applicable to the protection of the neurocognitive sphere. However, none of these provisions expressly contemplate the inference of brain information, which creates a significant legal vacuum.

A turning point was the 2023 León Declaration, adopted by European telecommunications ministers, which recognised for the first time that neurotechnology poses specific threats to fundamental rights and democracy. The declaration warns that the collection and manipulation of neurodata can influence thoughts and behaviours, open up new avenues for cyberattacks and generate systemic risks to individual freedoms. This institutional recognition reinforces the urgency of a specific legal framework at EU level.

The EU has also developed ethical documents which, although not focused exclusively on neurotechnologies, contain applicable principles: these include the *Ethics Guidelines for Trustworthy AI* and the reports of *the European Group on Ethics in Science and New Technologies*, which promote values such as human oversight, transparency, non-maleficence, justice and explainability. These principles are directly transferable to the treatment of technologies that interact with the nervous system.

4.3. OECD: Recommendation on Responsible Innovation in Neurotechnology (2019)

In 2019, the Organisation for Economic Co-operation and Development (OECD) published its Recommendation on Responsible Innovation in Neurotechnology, the first international instrument focused on the ethical governance of these technologies. This document highlights the need to promote a culture of anticipatory responsibility through ethical oversight in research and clinical application; algorithmic governance and risk assessment; enhanced protection of brain data; and the inclusion of democratic values in the design and deployment of neurotechnologies.

Although not binding, this Recommendation has served as a conceptual basis for the subsequent development of more demanding frameworks, such as those of UNESCO and the European proposals.

4.4. Council of Europe: Oviedo Convention (1997)

The Council of Europe, through the 1997 Convention on Human Rights and Biomedicine (Oviedo Convention), provides a legal framework of reference for medical and scientific applications on the human body. This treaty, which is binding on Spain, establishes fundamental guarantees such as informed consent, the prohibition of interventions without medical justification, and the protection of the integrity of the person.

Although the text does not explicitly mention neurotechnologies, several authors argue that its principles can be reinterpreted evolutionarily to encompass the protection of the nervous system and the mental sphere, especially in clinical or experimental contexts. However, the growing sophistication of these technologies suggests that the Convention, in its current state, may be insufficient and needs to be supplemented with additional protocols or partial reforms aimed at neuroprotection.

4.5. Organisation of American States (OAS)

At the regional level in the Americas, the OAS has adopted a Declaration on Neuroscience, Neurotechnologies and Human Rights, which emphasises the urgency of developing regional regulatory frameworks that safeguard mental privacy, cognitive integrity and freedom of thought.

This declaration marks a starting point towards common governance in Latin America, positioning the hemisphere as an active space in the global debate on neurodights and establishing principles that can also serve as inspiration for Europe.

4.6. Latin America: Chile and Brazil as benchmarks

Latin America has become a pioneering region in the field of legal neuroprotection. Chile is the first country in the world to constitutionally recognise neurorights through Law 21.383 (2021), which guarantees the protection of physical and mental integrity against neurotechnological interventions. This advance, which is highly significant in comparative terms, has been widely cited in Spanish and European doctrinal debate as an example of proactive regulation.

For its part, Brazil has initiated legislative debates on neurotechnology and neurodights, consolidating the region as one of the emerging poles in the legal formulation of principles of mental protection and institutionalised neuroethics.

5. Conclusions

The analysis developed in this paper allows us to affirm that neurotechnology represents one of the most complex and transformative legal challenges of the 21st century. The ability to record, infer and modulate neural activity not only introduces promising therapeutic applications, but also unprecedented tensions in the system of fundamental rights. This technology forces us to rethink the meaning and scope of essential constitutional notions such as personal autonomy, dignity, privacy and moral and physical integrity.

Unlike other technologies that process observable or behavioural data, neurotechnology accesses the most intimate core of the person: the mind. This direct access to mental life raises a new "legal space" that requires enhanced protection, not yet expressly recognised by Spanish or European law.

Despite the growing use of neurotechnologies in clinical and experimental settings, most countries around the world lack legislation regulating this area. Although Spain's current constitutional framework offers certain interpretative foundations (Article 10 CE on dignity, Article 15 CE on moral integrity, and Article 18 CE on privacy), it does not explicitly address the risks arising from brain reading or manipu-

lation. Therefore, an evolutionary hermeneutic effort or, where appropriate, specific legislative reform that clearly incorporates the protection of the mental sphere is required.

From a data protection perspective, both the GDPR and the LOPDGDD are insufficient. As recognised by the European Data Protection Supervisor (EDPS), neurodata is unique, highly sensitive and difficult to anonymise. The conceptual architecture of these standards does not anticipate the risks arising from the involuntary and predictive nature of neural data.

Some recent instruments mark promising advances. The Charter of Digital Rights, although not binding, includes in its section XXVI an explicit reference to neurotechnologies, proposing principles such as self-determination, control of personal identity and enhanced protection of neurodata.

For its part, the Draft Digital Health Law of Cantabria (2025) is the first legislative initiative in Spain to expressly recognise neurodights. However, this approach poses a risk of regional fragmentation and regulatory coordination, which could compromise the coherence of the state legal system.

At the international level, organisations such as the European Union, the Council of Europe, the OECD, the OAS and UNESCO have initiated relevant regulatory and ethical processes. The recent UNESCO Recommendation on the Ethics of Neurotechnology (2025) is the first international instrument to call for the protection of mental privacy and guarantee the inviolability of the human mind. However, there is still no binding and harmonised global framework that comprehensively regulates the use of these technologies.

In this context, Spain is in a strategic position: it has one of the largest scientific infrastructures in Europe in neurotechnology (Spain Neurotech), has incorporated neuroprotection principles into instruments such as the Charter of Digital Rights, and is leading pioneering legislative initiatives with the Draft Bill of Cantabria. This triple convergence positions the country as a potential international benchmark in the construction of a solid, ethical legal model in the field of neurodights.

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The market of the mind: neurotechnology, private companies, and regulation

FRANCISCO LUCIANO LIMA RODRIGUES[1]

Contents: Introduction; 1. The emergence of neurotechnology companies as new power players; 2. Qualitative mutation of neurodata & ontological insufficiency of the LGPD; 3. INadequacies of current legal frameworkS; 4. Neurotechnology and the risk to mental autonomy; 5. Possible regulatory paths; Conclusions; References.

Introduction

The emergence of innovative neurotechnology companies has proven to be an emerging power in the world, giving rise to a whole new dimension for contemporary law, which goes beyond strictly informational privacy to protect people's mental sovereignty. Neurolaw has established the backbone for protecting cognitive freedom, mental integrity, and psychological health in light of brain-computer interfaces. The human brain, as the ultimate repository of consciousness, memory, and personal identity, is no longer a naturally impenetrable territory, but has become the new object of extraction for so-called surveillance capitalism. In this scenario, the possibility of technological manipulation of the human mind poses direct threats to personal autonomy, demanding a legal response that transcends classic freedoms and focuses specifically on the psychic sphere.

In contemporary times, we observe that new technologies are bringing about a change in the object of capitalism, shifting the focus from material goods to the mining and monetization of psychic data, transforming it into the "oil" of the 21st century. Generative artificial intelligence has advanced from a passive position to direct interference in human perceptions, using behavioral engineering and stimuli that can unconsciously guide human behavior. Phenomena described by Shoshana Zuboff (2019) reveal that behavioral data is converted into predictive information to shape future decisions, resulting in the colonization of the mind by algorithmic logic. Episodes such as the Cambridge Analytica scandal symbolize the risk of a

[1] Doctor of Law from the Federal University of Pernambuco, with a research internship at the Faculty of Law of the University of Lisbon- Portugal. Full Professor of the Postgraduate Master's/Doctorate Program in Constitutional Law at the University of Fortaleza (UNIFOR). Associate Professor at the Faculty of Law of the Federal University of Ceará. Judge of the Court of Justice of the State of Ceará. Email: lucianolima@unifor.br

"neurogovernment" of behavior, where technology is mobilized not to expand human reasoning, but to replace and manipulate it en masse.

The inadequacy of current regulatory frameworks, such as the General Data Protection Law – LGPD (Law 13.709/2018), becomes evident when analyzing the ontological nature of neurodata, which transcends the definition of sensitive personal data. Brazilian legislation makes a serious categorical error by equating the dynamic and predictive recording of brain activity with static identifiers, such as fingerprints, failing to recognize the neurospecificity of consciousness. This legislative simplification reduces the protection of the mind to a matter of information security, leaving the door open for corporations to use synaptic maps for neurocognitive profiling purposes. Given the technical impossibility of effectively anonymizing neurodata, current regulations prove fragile in containing the extraction of information that the data subject has not yet consciously processed.

Through a comparative analysis, this study proposes an axiological reform inspired by Chile's constitutional pioneering, which elevated neurodata to the legal status of absolute physical and mental integrity. It is imperative that the Brazilian legal system advance toward guaranteeing mental sovereignty, establishing that the brain is the last frontier of privacy and that its violation for market interests violates human dignity. This paper argues that future regulation should prohibit the commercialization of raw neurodata and restrict the use of mind-reading technologies to strictly audited scientific and medical purposes. Only through a reform that understands the difference between information and consciousness will it be possible to ensure that technological progress does not culminate in the submission of the mind to the control of transnational capital.

1. The emergence of neurotechnology companies as new power players

Any discussion of the emergence of neurotechnology companies as new power players must include a brief account of the emergence of neurolaw and its consequences for the idea of privacy as a fundamental right.

Neurolaw emerged as an autonomous discipline in the early years of the 21st century, with contributions from the research of Marcello Ienca and Roberto Andorno (2017), which led to the development of the idea of legal guarantees for rights relating to cognitive freedom, mental privacy, mental integrity, psychological continuity, and equitable access to neurotechnologies, to be called neuro-rights.

The human brain, as the repository of consciousness, memory, and personal identity itself, would be the object of protection under neurolaw, in order to prevent nonconsensual external interference. Unlike the protection of classic freedoms, this would be oriented toward the mental sphere, considering that the possibility of technological manipulation of the human mind would pose a threat to personal autonomy.

Chile's Constitutional Reform Bill, enacted on October 25, 2021, and converted into Law No. 21,383, introduced a pioneering innovation in the global legal landscape by amending Article 19 of the Chilean Constitution to provide that "scientific and technological development must be at the service of the people, respecting life and physical and mental integrity".

This amendment is considered the definitive constitutional recognition of "neuro-rights," which provide legal protections for research (and technology) so that it does not interfere with the human mind. Its regulations require that all advances in neuroscience, artificial intelligence, and cognitive engineering put human beings first and that new technologies that act on brain functions cannot be used without the person's consent, including certainty regarding the scope of the authorization.

Theoretically, the Chilean reform places the centrality of the human person in the neurotechnological world and serves as an international precedent for the protection of cognitive freedom, mental privacy, and psychic integrity. In Latin America, this initiative inaugurates what is called humanistic neuroconstitutionalism, in which scientific development ceases to be an end in itself and becomes an instrument for promoting human dignity and plurality.

In Europe, the issue of psychic integrity in the face of advances in new technologies, as well as the possibility that such innovations may interfere with the human brain, has raised concerns within the Italian National Bioethics Committee (2023) and the European Parliament (2022), in the sense that it should be noted that brain-machine interactions must be preceded by informed consent, including a clear option to revoke authorization, in addition to meaningful human supervision at all times.

Reflection on the regulation of the use of generative artificial intelligence, data, and the need for privacy protection through the use of neurotechnologies will be addressed further below.

New technologies have sparked the interest of companies that have begun to produce equipment aimed at improving quality of life, as well as entertaining people, thereby changing their behavior through their connection to new equipment and its features and, as a consequence, producing data that has been monetized by companies, changing the object of capitalism by shifting the focus from material goods to data mining, selection, and sale, transforming it into the "oil" of the 21st century.

Contemporary artificial intelligence, especially generative AI, has advanced from a position where it only acted on data to, with neurotechnologies, interfering with human perceptions, when, through recommendation systems, social media platforms, and generative models operate based on behavioral engineering, that is, in the design of stimuli that unconsciously guide human behavior, transforming mental focus into a commodity.

Philosopher Shoshana Zuboff (2019) describes this phenomenon as surveillance capitalism, in which psychic and behavioral data are converted into predictive information to shape future decisions. The law, in protecting privacy and informational self-determination, faces a new dimension of challenge: the capture of inner freedom, that is, the colonization of the mind by algorithmic logic.

In 2018, the Cambridge Analytica scandal[2] revealed how data mining techniques and psychometric profiling were used to manipulate mass electoral choices through personalized messages. This episode illustrates how likely a neurogovernment

[2] The Cambridge Analytica scandal came to light in 2018, when it was revealed that the British company had collected, without consent, the personal data of around 87 million Facebook users, using it to create psychometric profiles and target personalized political advertising, especially in the US presidential elections (2016) and the Brexit referendum (2016). The case exposed the risks of large-scale behavioral manipulation and sparked global debates on privacy, data protection, and democratic integrity (Cadwalladr; Graham-harrison, 2018).

of behavior is, in which artificial intelligence is employed not to enhance human reasoning, but to replace it.

Experiments in brain-machine interfaces (BMIs), such as those conducted by Neuralink and Emotiv Systems, represent one of the most robust frontiers of contemporary neurotechnology. These interfaces act as a means of sending information between the human brain and an external device (computer, prosthesis, or digital) by capturing and reading emotions.

Neuralink (2024), a company started by Elon Musk in 2016 to study neural implants and artificial intelligence, has begun testing. In 2024, Neuralink obtained permission from the U.S. Food and Drug Administration (FDA) for the first human trials involving a chip implanted in the motor cortex. The project, known as telepathy, aims to help people with paralysis control digital services with just a few thoughts. But the tests have raised considerable ethical and safety concerns—about mental privacy, cognitive control, and reverse oncology processes.

Emotiv Systems (2023), founded in 2011 in Australia, provides non-invasive interfaces based on electroencephalography (EEG) sensors to capture brain waves in order to process emotion, attention, and mental function. Its products, the Emotiv Insight and Epoc X headsets, are designed for daily use (using the body to track one's emotions and thoughts, as well as to focus on one's behavior and work in industry) by the company in neuromarketing, with this in mind and emotional monitoring in institutions/education. However, unlike surgery, these machines raise bioethical issues, such as the misuse of neural data for corporate purposes and the lack of informed consent from users.

In both cases, there is a convergence with what several authors call "neurocapitalism"; the economic appropriation of mental and emotional processes that urgently needs to be protected by neuro-rights, so that the mind and subjective thought, presence, and identity as an individual can be safeguarded.

The concentration of power in the hands of the private sector that controls neurotechnology companies points to a serious risk to a person's cognitive privacy, considering that, as a rule, their technologies promote informational asymmetry, unbalancing the relationship between user and machine, especially due to the opacity of data and the resulting lack of transparency, in practice, in decision-making by the algorithm and not by the person, who often has a fragile conviction that they decided on something when in reality it was decided for them.

2. Qualitative mutation of neurodata & ontological insufficiency of the LGPD

The notion of neurodata transcends the old definition of sensitive personal data to place itself at the heart of human thought as information that is central to human subjectivity and dignity. Instead of biographical or biometric indicators, such as fingerprints or iris patterns, neurodata is a direct record (an electrochemical aspect of the nervous system) captured through brain-computer interfaces or neuroimaging sensors. They uniquely identify the individual, but translate the biological processes that underlie consciousness, thought, memory, and emotion. As Ienca and Andorno (2017) argue, this technology allows for a technical incursion into spheres of

intimacy that, until then, were considered the last bastion of absolute privacy—the *forum internum*.

The fundamental ontological difference lies in the fact that common personal data functions as an attribute of personality—an external representation of how the subject projects themselves socially—while neural data constitutes the very biological infrastructure of the mind. While the current informational paradigm, consolidated in laws such as the General Data Protection Law – LGPD (Law 13.709/2018), treats data as informational assets that can be "managed," neurodata challenges this logic by being the physical manifestation of subjectivity in its raw state (Brazil, 2018). The collection of this data allows for the inference of unconscious mental states and cognitive predispositions that the data subject has not yet consciously processed, which subverts the classic concept of informational self-determination, according to Stefano Rodotà's (2014) critical analysis of the "electronic body."

Given this complexity, there is a necessary and urgent criticism of Article 5 of the General Data Protection Law – LGPD (Law 13.709/2018), which classifies biometric data generically as sensitive personal data. In doing so, Brazilian legislation makes a serious categorical error by equating the recording of brain activity—which is dynamic and predictive—with a fingerprint, which is static and serves only for authentication. The General Data Protection Law – LGPD (Law 13.709/2018) fails to recognize neurospecificity, treating the "essence of consciousness" with the same regulatory rigor applied to an external physical characteristic. As Rafael Yuste (2017) points out, this legislative simplification reduces the protection of the mind to a matter of information security, leaving the door open for companies to use neurodata for neurocognitive profiling and neuromarketing purposes (Brazil, 2018).

The fragility of Article 5 of the General Data Protection Law – LGPD (Law 13.709/2018) becomes even more evident when confronted with the impossibility of anonymizing neurodata. Advanced studies in neurofingerprinting[3] demonstrate that the functional connectivity patterns of the human brain function as unique and unrepeatable biographical signatures. This makes the traditional anonymization methods required by Brazilian law technically ineffective in the long term. Once a private corporation stores the synaptic map, this data can be reidentified with almost absolute precision. As Shoshana Zuboff (2019) argues, the biological uniqueness of the brain means that the leakage of neural databases has permanent and irreversible consequences, exposing subjectivity to the perpetual scrutiny of artificial intelligence systems.

The informational asymmetry between the data owner and the corporations that control brain-computer interfaces reveals that the consent provided for in the General Data Protection Law – LGPD (Law 13.709/2018) is an insufficient tool. By processing neurodata through *deep learning* algorithms, companies can anticipate desires and fears at subliminal levels, bypassing the barrier of conscious will. Brazilian law assumes a "data subject" who has full governance, but ignores the neurocognitive hypervulnerability of those whose brain chemistry is monitored. The pioneering nature

[3] Neurofingerprinting is a technique for identifying individuals based on unique patterns of neural activity, captured by means such as EEG or fMRI. Unlike traditional biometrics, these patterns not only identify the individual, but can also reveal cognitive or emotional traits. Due to its uniqueness and difficulty in anonymization, it poses direct risks to mental privacy and neurocognitive integrity.

of Chile's Constitutional Reform demonstrates that protection must migrate from mere "informational privacy" to the guarantee of mental sovereignty.

In addition to the classification flaw, the liability regime of the General Data Protection Law – LGPD (Law 13.709/2018) needs to be adapted to the concept of constitutionally qualified risk activities. Consumer neurotechnology companies are not mere service providers; they act as guardians of the infrastructure of consciousness. The application of the current regime allows *ethics washing* practices to thrive. The criticism here is axiological: legal protection should not only aim at the integrity of databases, but also at the immunity of human decision-making from external interventions, something that the United Nations (UN) is already beginning to discuss from the perspective of freedom of thought.

Finally, overcoming the gap left by current legislation requires recognizing the brain as a territory of absolute protection. It is imperative that the legal system establish that the barrier of the skull is the last frontier of privacy and that its violation for commercial interests strikes at the very core of human dignity. Future regulation must prohibit the commercialization of raw neurodata and restrict the use of mind-reading technologies to strictly audited scientific and medical purposes. Only through a reform that understands the ontological difference between "information" and "consciousness" will it be possible to ensure that technological progress does not culminate in the submission of the mind to the control of transnational capital.

The criticism of the classical informational paradigm lies in its inability to distinguish between data that describes external circumstances and data that constitutes the very infrastructure of human subjectivity. The traditional model, which underpins laws such as the General Data Protection Law – LGPD (Law 13.709/2018), views information as an object external to the subject, something that can be "managed," "carried," or "alienated" through adhesion contracts. However, with regard to neurodata, this separation between subject and object collapses, since neuronal electrical activity is not a representation of the person, but their own biological manifestation. As Stefano Rodotà (2014) argues, data protection must evolve towards the protection of the "electronic person," where the body and information merge into an inseparable unit of dignity.

The power asymmetry imposed by Surveillance Capitalism, a concept coined by Shoshana Zuboff (2019), transforms the brain into a territory for the extraction of "behavioral surplus value." The informational paradigm fails by allowing click consent to legitimize access to mental processes that the user themselves does not understand. There is a "hypervulnerability" of the data subject, as access to neural data allows corporations to influence decisions through subliminal stimuli. Legally, this means that freedom of choice is being undermined at the source, requiring the law to intervene to guarantee mental sovereignty against technical manipulation by the private sector.

Finally, the transition to a model that recognizes neurodata as an inseparable extension of the person is the only way to safeguard human dignity in the face of pressure from the neurotechnological market. It is imperative that legal regulation abandon the reductionist view of data as an object and adopt the view of data as a being, establishing mental integrity as an inalienable right, as enshrined in Chile's pioneering Constitutional Reform. Resistance to the commodification of the mind

requires that the nervous system be treated as a legal sanctuary, where the barrier of the skull acts as an insurmountable limit to the sovereignty of capital. Only by anchoring protection in the ontology of being can the law prevent technology from transforming subjectivity into a byproduct of the economy.

3. Inadequacies of current legal frameworks

The paradigm of personal data protection, consolidated by legislation such as the General Data Protection Law (LGPD) (Law 13,709/2018), finds its ontological limit in the nature of neurodata. While traditional data protection was designed to safeguard informational self-determination in conscious digital interaction environments, neurodata captures preconscious biological processes. The limit lies in the fact that neural data is not a choice to share, but an involuntary byproduct of biological existence, which makes common informational safeguards insufficient to protect psychic integrity.

The fragility of informed consent is the most obvious breaking point in this scenario. In classical civil law, consent presupposes the agent's full knowledge and freedom; however, when faced with brain-computer interfaces (BCIs), the user is unable to predict the extent of correlations that AI algorithms can extract from their neural signals. Consent becomes a "legal fiction," as no one can validly consent to the extraction of information whose existence or future predictive utility they are unaware of by private corporations.

In the field of Consumer Law, the concept of neurocognitive hypervulnerability emerges. Unlike the technical or economic vulnerability already provided for in the General Data Protection Law – LGPD (Law 13.709/2018), neurocognitive vulnerability refers to the individual's biological inability to resist stimuli that operate below the threshold of consciousness. When companies use neurodata to optimize engagement or induce consumption, they are not only persuading, but circumventing the consumer's rational defense mechanisms, violating the principle of dignity and transparency.

Corporate self-regulation and compliance programs have been presented by Big Tech as the solution to the ethical dilemmas of neurotechnology. However, in practice, these initiatives often degenerate into *ethics washing*, a public relations maneuver that uses vague ethical language to avoid the imposition of legal norms. Merely formal compliance with internal ethical guidelines does not replace due process and the necessary external control over technologies that can alter an individual's perception of reality.

Current regulatory models, based on the control of "data flows," fail to consider neurodata as an extension of physical and mental integrity. Current regulation focuses on "secure processing," when it should focus on "prohibiting access" to certain spheres of the human mind. There is an extrinsic limit to frameworks such as the General Data Protection Law – LGPD (Law 13.709/2018): they were made to regulate the information market, not to protect consciousness against colonization by private capital.

Neurocognitive hypervulnerability requires an absolute reversal of the burden of proof in neurotechnological consumer relations. Given the opacity of neural

decoding algorithms, consumers will never have the technical means to prove that their will has been manipulated. Thus, the responsibility of companies must be objective and based on the risk of the activity, assuming moral damage (*in re ipsa*) whenever there is a deviation from the purpose of neurodata or a failure in the security of the neural device.

The insufficiency of "click" digital consent demonstrates the need for qualified and assisted consent protocols. In the context of neurotechnologies, consent should be renewable and specific to each layer of neural data extracted, preventing a generic authorization from opening the door to the reading of emotional states or deep intentions. Freedom of choice, the foundation of private law, is undermined when the object of the contract is the very tool of choice: the brain.

The phenomenon of *ethics washing*[4] is particularly dangerous in neurotechnologies because it creates a false sense of legal certainty. Companies that advertise independent ethics boards but keep their algorithms under trade secret prevent the public audit necessary to ensure that there is no "neuro-discrimination" or behavioral manipulation. Ethics cannot be a marketing accessory, but an insurmountable limit to unregulated technological innovation.

The limits of personal data protection also run up against the technical impossibility of effectively anonymizing neurodata. Since each brain has a unique "neuro-fingerprint," the concept of anonymization in the General Data Protection Law (LGPD, Law 13.709/2018) becomes useless. Any neural database can be re-identified with the help of AI, which means that sharing this data, even if supposedly anonymous, poses a perpetual risk to the privacy of the data subject, who cannot change their neural structure in the event of a leak.

State regulation must therefore evolve towards the positivization of constitutional neuro-rights, following the example of Chile's Constitutional Reform (Law 21.383) . Without a higher-level norm establishing the mind as an unavailable asset, data protection laws will continue to be interpreted in a utilitarian manner, allowing the market to dictate the limits of mental privacy in the name of technical progress or consumer convenience (Chile, 2021).

Neurocognitive hypervulnerability also raises questions about the validity of legal transactions entered into under the influence of neurostimulation or constant neural monitoring. If an interface can detect a consumer's moment of greatest emotional fragility and present an offer precisely at that moment, "consent addiction" is operated at the biological level. Contract theory will need to develop mechanisms to nullify transactions based on abusive neurobehavioral exploitation.

Traditional digital compliance focuses on avoiding administrative fines, but neuro-compliance must prioritize the preservation of the user's personal identity. This requires companies to adopt the principle of Neuro-Privacy by Design,[5] whose opera-

[4] Ethics washing is the practice by which organizations publicize ethical commitments or create committees and codes of conduct to appear morally responsible, without promoting real structural change. It functions as a reputational strategy aimed at avoiding stricter regulation. In the technological field, it often masks systemic risks under vague and non-binding ethical language.

[5] Neuro-Privacy by Design is the principle that requires the integration of mental privacy protection from the design phase of any brain-computer interface. In neurotechnology, this model requires that the *hardware* and *software* architecture process neural signals locally (at the edge), preventing, by default, the storage of raw neurodata in corporate

tionalization involves the adoption of structured governance tools, among which the Privacy Impact Assessment (PIA) stands out. This impact assessment process allows organizations to identify vulnerabilities and privacy risks even before data processing begins, facilitating the documentation of decisions and the demonstration of the principle of accountability. In the context of neurotechnologies, the PIA becomes essential for mapping how the collection of raw neural signals can affect the autonomy of the data subject.

In terms of comparative law, the main normative reference is Article 25 of the European Union's General Data Protection Regulation (GDPR) . This provision establishes the mandatory nature of Privacy by Design and by Default, determining that privacy protection is not an optional accessory, but a default setting integrated into the technical development of any information system (European Union, 2024).

The application of protection from the genesis of the system refers to the seminal contribution of Ann Cavoukian (2021) , whose Privacy by Design model establishes that privacy should be proactive, not reactive. In the field of neurotechnology, this legacy translates into the need for device architecture to natively and by default prevent the extraction of raw neurodata that is not strictly necessary for the functionality of the system.

The limitations of current regulatory models are compounded by the speed of corporate innovation relative to slow legislative action. While lawmakers are still debating the ethics of generative AI, companies are already testing neural implants in humans. This requires dynamic or principle-based regulation (rather than just strict rules), which allows regulatory agencies to intervene immediately in the face of new risks to mental autonomy not provided for by law.

The fragility of consent is also evident in the workplace. Neurotechnologies used to monitor employee fatigue or productivity create an environment of total surveillance, in which employee consent is compromised by economic dependence. Without clear regulation, workers' mental autonomy is sacrificed in the name of productive efficiency, transforming the brain into a monitored cog in the digital assembly line.

Current regulatory frameworks fail to treat neural damage as merely informational damage. The violation of neurodata can result in profound existential damage, affecting self-perception and the continuity of identity, which makes it necessary, in the case of the Brazilian legal system, to update it to provide for the repair of neurospecific damage, recognizing that the mind is the factual support for all personality rights.

Finally, the regulatory challenge is to prevent the human mind from becoming the next territory for colonization by private capital. The limits of personal data protection have been reached; now, we are entering the era of defending psychic integrity. The transition to a regime of neuro-rights is not an option, but a civilizational necessity to ensure that human beings remain the subject, and not the object, of technological development.

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clouds. Its application aims to mitigate the risks of subliminal monitoring, ensuring that the technology is structurally incapable of collecting information from the psyche that exceeds its stated functional purpose.

4. Neurotechnology and the risk to mental autonomy

Mental autonomy must be understood as the cornerstone of the entire edifice of fundamental rights, for without sovereign control over one's own thought processes, any other civil or political freedom becomes a legal fiction. Historically, the law has protected the external manifestation of will—freedom of expression—assuming that the internal process of forming that will was a naturally impenetrable territory. However, the rise of brain-computer interfaces (BCIs) by private companies breaks this "biological isolation," allowing external stimuli to access and influence cognition even before conscious perception. Thus, mental autonomy ceases to be a fact of nature and becomes a legal right that requires active protection against the intrusion of technologies that seek to map, predict, and ultimately guide human thought.

Cognitive freedom emerges, in this context, as a multidimensional right that encompasses both the right to use neurotechnologies to improve the "self" and the right to refuse to be monitored or influenced by them. It represents self-determination at its deepest level: control of one's own consciousness. In the mind market, this freedom is severely threatened by the ability of artificial intelligence algorithms to translate neurodata into highly accurate psychological profiles. When private capital holds the means to read and write brain activity, cognitive freedom becomes the main legal battleground today, requiring that the individual be the sole arbiter of their inner life, free from subliminal manipulations that aim to transform cognition into a constant flow of consumption.

Overcoming the classic paradigm of privacy is urgent, as the idea of "informational privacy" inherited from the 20th century is insufficient to deal with neural intrusion. Traditional privacy focuses on control over who has information about us (such as our address or purchase history), but neurotechnology requires the protection of "mental privacy," which is control over who can access our own brain activity. The privacy paradigm focuses on data as an object; the new paradigm must focus on data as a subject. While privacy can be negotiated or relativized in certain social contexts, mental privacy must be treated as an absolute right, as its violation exposes not only data, but the very biological structure that allows the individual to be who they are.

It is imperative to establish mental integrity as an autonomous legal right, unrelated to mere physical integrity or mental health in the clinical sense. Mental integrity refers to protection against any intervention that alters or monitors brain function without specific and qualified consent. In the hierarchy of legal rights, the mind must occupy the top, as it is the factual support for the existence of all other rights: without an intact and autonomous mind, there is no dignity, no property, and no freedom. The recognition of mental integrity as a value per se prevents neurotechnology companies from justifying the extraction of neurodata under the pretext of "improving the user experience," prioritizing the protection of the psychic sanctuary over market efficiency.

The principle of human dignity is based on the idea that a person should always be treated as an end in themselves, and never as a means to someone else's ends. However, the commercial exploitation of neurotechnology reverses this Kantian logic by transforming brain activity into raw material for corporate profit. The

instrumentalization of the mind occurs when neurodata is collected to optimize engagement algorithms or induce emotional states that favor impulsive consumption. Prohibiting the instrumentalization of the mind means declaring that human consciousness is a non-marketable territory, immune to the laws of supply and demand, and that any technology that seeks to "hack" the human will violates the essential core of dignity.

The prohibition of subliminal commercial instrumentalization is the necessary barrier against what can be called "neuro-surveillance." Unlike traditional surveillance, which monitors actions, neurosurveillance monitors intentions and feelings. When an interface detects a pattern of stress and translates it into an opportunity to sell a drug or service, the mind is reduced to a profit optimization tool. The law must be emphatic in prohibiting practices that use neurodata to bypass the critical filter of consciousness. Protection against instrumentalization is not intended to impede scientific progress, but to ensure that technology is an instrument of emancipation for the individual, rather than an invisible shackle imposed by the private power of Big Tech.

Mental autonomy also faces the challenge of "neurocognitive hypervulnerability." In consumer relations, it is recognized that certain people are more vulnerable, but neurotechnology makes all human beings hypervulnerable, as machines operate at a speed and with a precision that the biological brain cannot keep up with or audit. If a company can influence the user's neuroplasticity through continuous stimuli, the very notion of "free will" collapses legally. Therefore, regulation must presume the vulnerability of the individual and impose very strict duties of care on companies, treating any misuse of neural data as a very serious violation of human dignity, subject to punitive deterrent sanctions.

Mental integrity, as an autonomous legal right, allows the judiciary to punish "neural existential damage," even if there is no visible physical damage or diagnosed psychiatric pathology. The mere fact of having one's mental privacy invaded by a company's neural decoding system already constitutes an offense against personality. This new legal understanding is essential to prevent the law from becoming obsolete in the face of the "dematerialization" of human rights violations. If the mind is the seat of identity, any unauthorized intervention is, by definition, an assault on the person. Therefore, legal protection must be preventive and proactive, based on the precautionary principle, preventing market experiments from compromising the cognitive health of future generations.

In the field of civil liability, the prohibition of the instrumentalization of the mind underpins the theory of integral risk. Companies that develop Brain-Computer Interfaces (BCI) assume the risk of manipulating the essence of humanity. Thus, if a mood induction algorithm causes harmful behavioral changes, the company must respond objectively. Cognitive freedom does not allow transactions in which the user "pays" with their autonomy to access a service. The law must establish that certain personality rights, such as sovereignty over one's own thoughts, are unavailable, rendering null and void any contractual clause that seeks to authorize the commercial exploitation of neurodata for behavioral influence purposes. (Yuste; Goering, 2017)

Mental autonomy must also be protected against "neurodiscrimination." If the mind ceases to be private, individuals may be prejudged by their neural predisposi-

tions even before they act. Companies could select employees based on "synaptic efficiency," or insurers could adjust premiums based on emotional profiles extracted via neurotechnology. Human dignity prevents human beings from being reduced to a brain "score." Mental integrity, as an autonomous good, ensures that each person has the right to keep their inclinations and thoughts protected from automated judgment, preserving the plurality of human experience against the standardization imposed by neural optimization algorithms.

Cognitive freedom necessarily implies the protection of "identity continuity." Neurotechnologies that promise cognitive improvements can, if poorly regulated, alter the perception of "who I am," generating alienation of the subject in relation to their own self. As warned by UNESCO's International Bioethics Committee (Unesco, 2021) , neurotechnology has the potential to modify the neural substrates of mental states, which could lead to a rupture in an individual's life history, making it difficult for them to recognize themselves as the same subject over time. The law must ensure that technology does not erase memory or alter personality in a coercive or market-induced manner. Mental integrity protects the right to be the same over time. Human dignity requires that technology be a support for identity, not a mechanism for reengineering the soul in the service of business models that profit from emotional instability and digital dependence.

Overcoming the paradigm of informational privacy leads us to the concept of "*Habeas Mens*." Just as Habeas Corpus protects the body against arbitrariness, *Habeas Mens* should protect the mind against monitoring and manipulation. This new legal remedy would protect mental autonomy against the forced or surreptitious extraction of neurodata by companies. According to Ienca and Andorno (2017), the right to mental privacy should protect the individual's "inner world" against unauthorized access, ensuring that the intimate forum remains a sanctuary inaccessible to the state and corporations. Human dignity in the 21st century necessarily involves the protection of the brain. Individuals must have the power to "erase" their neural traces and prevent their synaptic activity from being used to train psychological profiling AIs, ensuring that their essence remains inaccessible to the gaze of capital (Yuste et al., 2017).

Prohibiting the instrumentalization of the mind is an ethical imperative against the "colonization of the unconscious." Traditional marketing tried to convince consumers; aggressive neuromarketing tries to seduce the biological brain. When the law allows companies to map the brain's reward centers to create addictive products, it allows for the chemical enslavement of the subject. Mental autonomy requires that the process of desire and choice remain sovereign. Regulation must prohibit interfaces that use neurodata to create bonds of dependency or to exploit cognitive vulnerabilities, reaffirming that human beings are the ultimate goal of technological innovation, and their minds a sacred territory of free will.

Human dignity prohibits the mind from being treated as 'data exhaust'. The paradigm of informational privacy usually accepts that secondary data is collected without greater rigor, but in the case of neurodata, there is no unimportant data, since each neural signal composes the mosaic of personality (Ienca; Andorno, 2017). Establishing mental integrity as an autonomous legal right implies that minimal collection of neural data should be the absolute rule. The law should require that processing

occur exclusively on the user's device (on-device processing), as recommended by UNESCO (2021), preventing the formation of 'brain banks' that would pose an existential threat to democracy and individual freedom.

Finally, the conclusion of this theoretical analysis reaffirms that the market of the mind cannot be a zone of legal anomie. The transition to the paradigm of mental integrity is the necessary response to the voracity of surveillance capitalism. Protecting mental autonomy, cognitive freedom, and human dignity against commercial exploitation is not only a task for lawyers and legislators, but a mission in defense of the very essence of what it means to be human.

5. Possible regulatory paths

The regulation of neurotechnologies must be primarily structural and based on a multidimensional risk analysis, overcoming the reactive regulatory model that has historically characterized Digital Law. The starting point for any normative discussion must be the recognition that neurotechnology is not an incremental evolution of information technology, but a paradigm shift that touches the core of human dignity. Therefore, risk-based models should classify brain-computer interfaces (BCIs) into categories of existential danger, as suggested by the Council of Europe (2020) in its guidelines on human rights and converging technologies.

The pioneering nature of Chile's Constitutional Reform (Chile, 2021) offers a global reference model by elevating neurodata to the legal status of absolute physical and mental integrity. In the Chilean scenario, the legislation did not limit itself to regulating the flow of information, but changed the ontological status of human beings in relation to machines, establishing that no one can intervene in brain activity without rigorous ethical and clinical justification. Following the Chilean paradigm, Brazil advocates the need for a Proposed Amendment to the Constitution (PEC) of parliamentary initiative that elevates mental integrity to the status of a fundamental right (Art. 5, CF), as suggested by experts in Digital Law and Neuroethics (Brazil, 1988).

The best path to effective new regulation would be to impose selective regulatory moratoriums, especially aimed at suspending commercial uses of neurotechnology in sectors such as advertising, given the extreme technical asymmetry between the hardware developer and the end user, where the risk of subliminal manipulation is so high that the state must act preventively. As discussed in the UNESCO Report (2021) , these moratoriums would allow the scientific community to debate the long-term impacts of algorithm-induced neuroplasticity, preventing society from becoming an open-air laboratory.

The implementation of Neuro-Privacy by Design should be established as an unavoidable technical and legal requirement. This concept establishes that device architecture should, by default, prevent the sharing of raw neurodata with external servers. The processing of neural activity must occur locally on the device (at the edge). By making privacy by design the norm, regulators remove the possibility for companies to form centralized neural databases, mitigating the risk of catastrophic leaks that would compromise the mental privacy of millions, following the data protection principles advocated by Ann Cavoukian (2021) .

Following the global trend inaugurated by the European Union's AI Act, neurotechnology regulation should provide for an Absolute Prohibition on Manipulation (European Union 2024). This means banning any system that uses subliminal or dopaminergic reinforcement techniques via neural interface to distort human behavior. Cognitive manipulation via neurotechnology is qualitatively superior to traditional manipulation, as it operates directly on the brain's reward centers. Brazilian sectoral regulation should establish that any attempt to "hack" free will will be punished with discontinuation of service and criminal liability for managers.

Specific sectoral regulation for the field of neurotechnology should be structured on fundamental principles that differ from classical civil law, focusing on the inalienability of neurodata. Unlike common personal data, neurodata should be treated under the legal regime of human organs: its commercialization should be prohibited as a matter of principle. As Rafael Yuste (2017) points out, brain data should be understood as part of the self and not as a commodity. By establishing that the biological basis of thought is unavailable, the regulator protects the essential core of human dignity against the predatory logic of the market.

Another essential structuring principle is that of Cognitive Justice and Equitable Access, which aims to prevent the formation of an evolutionary gap between 'augmented' individuals and those without access to such tools. A specific legal regime must provide mechanisms to prevent cognitive enhancement neurotechnologies from becoming the exclusive privilege of economic elites. As analyzed by Ienca and Andorno (2017), the restricted availability of these tools could consolidate a 'cognitive divide', requiring the State to act as a guarantor of democratic access. It is imperative to prevent technological advances from being used as instruments of social coercion, especially in environments such as the labor market, thus preserving the plurality of forms of consciousness.

The regulatory authority must have the power to conduct periodic algorithmic audits on neural decoding systems. It is not enough for the company to claim that it respects privacy; the source code must be subject to public scrutiny to ensure that there are no hidden mechanisms of behavioral induction. This path requires technical training by the State to train teams of "neuro-auditors." Neuroalgorithmic transparency is the only safeguard against the opacity of Big Tech, as warned by Shoshana Zuboff (2019) about the extraction of "behavioral surplus value" from the human unconscious.

In the field of civil liability, the most appropriate regulatory path is the adoption of Qualified Objective Liability for Integral Risk. Given the intrusive nature of neurotechnology, the developer must be liable for any damage to mental integrity, regardless of fault. The mere fact of placing a device that accesses the central nervous system on the market creates a duty of absolute guarantee. This regime, based on the Theory of Enterprise Risk in Brazilian Law, reverses the logic of capital and guarantees an effective system of checks and balances against uncontrolled experimentation on human beings.

In Contemporary Civil Law, the exegesis of neural decoding algorithms cannot be dissociated from the principle of the Social Function of Property (Art. 5, XXIII, CF/88) (Brazil, 1988). Although neurotechnology companies claim protection for their systems via Trade Secrets or Patents, the nature of the processed

object — human synaptic activity — imposes inherent limits on these intellectual property rights.

The "hacking" of free will for commercial profiling purposes transgresses the barrier of the legality of the contractual object. As classical civil law doctrine teaches, the autonomy of the will finds its insurmountable limit in the dignity of the human person. Thus, any contractual clause or algorithmic architecture that seeks to transform the flow of consciousness into an asset exclusively owned by the company must be declared null and void, for violating public order norms and personality rights, which are, by definition, inalienable and non-transferable, under the terms of the Brazilian Civil Code (Brazil, 2002).

Mental sovereignty, therefore, functions as a super-principle that subordinates market efficiency. The law cannot allow trade secrets to serve as a shield for the opacity of systems that extract "behavioral surplus value" (ZUBOFF, 2019). On the contrary, regulation must require Maximum Algorithmic Transparency: the source code that interacts with the human mind must be auditable, ensuring that the "psychic sanctuary" does not become a colony of private exploitation.

Regulatory paths must converge to create a Civil Framework for Neurotechnology that consolidates the principles and rules discussed. This framework must therefore include a legal version of resistance to the intrusion of the mind by private capital, and the human brain must be the basis of subjectivity. By taking the initiative based on constitutional neuro-rights and the architecture of protection and safeguarding citizens, Brazil positions itself on the global stage so that the market of minds never overrides human values.

Conclusions

The study shows that the "Mind Market" cannot survive either in a regulatory vacuum or in corporate self-regulation, which sometimes becomes a moral laundering strategy. Current informational paradigms are becoming exhausted, even though neurodata serves as the very basis of human subjectivity and the foundation of all personality rights: it is factual at all levels and is not subject to questioning. Law must migrate from controlling data flows to absolutely guaranteeing psychic integrity, recognizing that the mind is the territory of absolute protection of dignity. The centrality of the human person must act as an insurmountable limit to innovation, ensuring that the individual remains the subject, not the object, of accelerated technological development.

Overcoming neurocognitive hypervulnerability requires the Brazilian legal system to adopt a proactive and structuring stance, overcoming the reactive regulatory model that characterizes classic Digital Law. In Brazil, there is a call for a Proposed Amendment to the Constitution (PEC) that elevates mental integrity to the status of a fundamental right, ensuring that the brain remains immune to predatory commercial exploitation. The responsibility of companies must be objective and based on integral risk, assuming moral damage *in re ipsa* whenever there is a deviation from purpose or violation of mental privacy. This rigor is necessary because manipulation via neural interface operates directly on the brain's reward centers, bypassing the consumer's rational defense mechanisms.

The implementation of Neuro-Privacy by Design must be established as an unavoidable technical requirement, forcing the processing of neural signals exclusively on the user's device. By making privacy design a binding standard, the regulator prevents the formation of centralized neural databases and mitigates the risk of catastrophic and irreversible leaks. Additionally, the State must be equipped with the technical capacity to perform periodic Algorithmic Audits, training teams of "neuro-auditors" capable of penetrating the opacity of Big Tech architectures. Neuroalgorithmic transparency is the only effective safeguard against the extraction of behavioral surplus value from the human unconscious and the subliminal manipulation of desires and fears.

Ultimately, the transition to a robust regime of neuro-rights is not just a technical choice, but a civilizational necessity to ensure the survival of mental autonomy and human plurality. Regulatory paths must converge toward the creation of a Civil Framework for Neurotechnology that establishes the inalienability of neurodata and guarantees cognitive justice and equitable access. Protecting the mind against commercial exploitation means reaffirming that consciousness is a non-marketable territory, immune to the laws of supply and demand. Only by anchoring protection in the ontology of being can the law prevent technology from transforming subjectivity into a byproduct of the economy, ensuring freedom to think and feel without the surveillance of capital.

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Methodological Transparency Note: Use of Artificial Intelligence.

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The quiet erosion of mental privacy: corporate cognitive biometric data practices and the limits of Criminal Law

JANNA DA NÓBREGA SOUZA[1]

A preliminary overview

By their very nature, emerging technologies function as powerful drivers of progress and the expansion of human capabilities. At the same time, however, they entail a range of risks that are often readily apparent to those who design and develop them yet remain opaque within the cognitive horizon of their end users. Within this horizon of ambivalence, technologies of a dual or multiple nature—namely, those whose functionality, scope, and effects are redefined by the specific context in which they are deployed—introduce an additional layer of normative complexity. They give rise to scenarios in which the boundaries between instrumentally valuable uses and potentially harmful ones become porous, fluid, and contingent, shaped by contextual factors that dissolve any clear-cut distinction between utility and threat (Khan *et al*., 2024).

Among the most salient manifestations of this phenomenon are neurotechnology. Even a preliminary conceptual analysis reveals the emergence of an exceptionally broad and complex domain of intervention, encompassing devices, systems, and procedures designed to measure, access, monitor, analyze, predict, or directly modulate the nervous system. These technologies are deployed with the aim of elucidating, influencing, restoring, or even anticipating neural structure, functional dynamics, and patterns of activity (UNESCO, 2025). From a strictly biomedical standpoint, this unprecedented capacity to act upon the neural substrate translates into clinical potential of the highest significance, with transformative implications for contemporary therapeutic practice. The progressive refinement—particularly in terms of precision,

[1] Assistant Professor of Criminal Law at the University of Jaén (Spain). PhD from the University of Murcia. Master's degree from the Carlos III University of Madrid. jda@ujaen.es

targeting, and integrative capacity—of techniques such as deep brain stimulation, transcranial magnetic stimulation, and brain–computer interfaces has enabled forms of intervention that, until recently, lay beyond the boundaries of clinical feasibility in the treatment of a wide range of pathological conditions (López-Silva *et al*., 2024).

Nevertheless, the reach of these advanced forms of technical interaction with the nervous system extends far beyond a mere expansion of the existing clinical toolkit. When examined from a market-oriented perspective—and in clear continuity with the expansionary dynamics that accompanied the rise of biotechnologies associated with the Human Genome Project—the sector appears to be undergoing a process of strategic realignment directed towards the creation of new domains of value. This shift transcends the boundaries of therapeutic intervention and increasingly moves into the sphere of consumer-oriented applications, driven by the proliferation of non-implantable solutions designed for direct access by the general public (Yuste, 2023). Without yet engaging in a detailed analysis of their specific features, it is nonetheless evident that this progressive integration into areas such as personal well-being, digital leisure, meditative practices, and everyday assistive technologies is far from axiologically neutral. Rather, it enables an increasingly granular interpretation of individuals' inclinations, dispositions, and preferences, while simultaneously opening avenues for shaping their very configuration, thereby placing the notion of individual choice itself under normative strain (Wajnerman-Paz, 2024).

Human autonomy and freedom of thought ultimately depend on the preservation of mental privacy, understood as the individual's capacity to govern cognitive processes and to control the flow of neural data derived from them. This core of self-determination has, for that very reason, historically remained shielded from external observation, systematic interference, or technological oversight (Khan *et al*., 2024). Within this framework, the concept of neural data assumes particular significance, referring to records—both quantitative and qualitative—that pertain to the structure, activity, and functional dynamics of the nervous system (UNESCO, 2025). Building on this initial delineation, a strand of the scholarly literature has advanced an expansive conception of cognitive biometric data, intended to encompass not only neural measurements obtained through direct means, but also physiological and behavioural data whose collection, integration, and analysis make it possible to infer, with increasing degrees of precision, mental states of a cognitive, affective, and conative nature (Genser *et al*., 2024). This characterization underscores the exceptional sensitivity of such data, as these measurements do not merely capture discrete physiological functions but are intrinsically connected to deep layers of subjective experience, often inaccessible to conscious articulation.

When this body of information becomes subject to systematic processing by large corporations, its capacity for disclosure is substantially intensified. The aggregation and structuring of large-scale volumes of cognitive biometric data, their processing through advanced algorithmic modelling and machine-learning techniques, and their integration with other digital data streams enable not only the inference of contemporaneous mental states, but also the anticipation of behavioural patterns and the construction of individualized profiles. In this process, such records no longer function merely as technical inputs; they are reconstituted as strategic assets endowed with significant economic value (Magee *et al*., 2024). This shift relocates the

core concern within a logic of instrumental appropriation of objectified mental life. The progressive normalization of neurotechnological artefacts in everyday practices places the entities responsible for their design and commercialization in a structurally advantageous position to consolidate expanding repositories of brain scans and other records of neural activity.

Far from representing an isolated or incidental development, this trajectory mirrors a pattern previously observed in the domain of direct-to-consumer genetic testing, where market expansion was accompanied by the accumulation of extensive repositories of highly sensitive information (Genser *et al*., 2024). The value-generating potential inherent in such datasets extends well beyond the purposes that initially justified their collection, insofar as their transfer, commercialization, or indirect exploitation facilitates the emergence of secondary processing circuits oriented toward predictive modelling and the development of products or services grounded in inferences concerning behaviour, health status, or individuals' internal dispositions. This functional reorientation of the uses assigned to the collected data opens a horizon of downstream applications that are scarcely discernible at the moment of capture, thereby undermining the foundations of informed consent while simultaneously introducing structural risks of discrimination, subtle forms of manipulation, and enduring asymmetries of power over the mental sphere.

The underlying dynamic, still at an incipient stage in judicial practice, found an early and particularly illustrative expression in the judgment issued by the Supreme Court of Chile on 9 August 2023. In that decision, the Court upheld a constitutional protection claim brought against the neurotechnology company Emotiv, finding an infringement of the fundamental rights to privacy and psychological integrity as enshrined in Article 19 of the Chilean Constitution (Muñoz *et al*., 2024). Within the Spanish legal system, the most salient criminal-law challenge arising from this emerging reality—one that has yet to receive consolidated treatment in case law—lies in the difficulty of accommodating the conduct in question within the existing catalogue of criminal offences. This circumstance inevitably calls for an examination of the potential applicability of Article 197 of the Criminal Code, located in Chapter I of Title X, which governs offences concerning privacy, personal image rights, and the inviolability of the home. A closer analysis of the provision's structural elements and normative design, however, reveals, even at an initial stage, a series of tensions that complicate such subsumption, particularly in light of the ontological and functional specificity of neural data (Cornejo-Plaza *et al*., 2024).

A further issue of particular doctrinal significance concerns consent (Rainey *et al*., 2021). The absence of a legally valid authorization on the part of the holder of the protected legal interest constitutes a central criterion for delineating the scope of criminal liability under the relevant provision. This circumstance shifts the focus of the analysis towards the breadth and indeterminacy of the mechanisms currently employed to obtain consent in technologically complex environments, which are often marked by pronounced informational asymmetries and by modes of acceptance that sit uneasily with fundamental requirements of freedom, adequate information, and purpose specificity. Against this background, the present chapter undertakes a critical and systematic examination of the contours and limits of criminal-law protection in response to the commercial exploitation of neurotechnological artefacts. It evaluates,

on the one hand, the capacity of Article 197 of the Spanish Criminal Code to operate as an effective safeguard of mental privacy and, on the other, the normative tensions generated by the requirement of legitimate authorization in a context shaped by the rapid expansion of neurotechnology and the progressive transformation of human interiority into an object of economic exchange.

1. Privacy protection under spanish Criminal Law

The etymological genealogy of the term *secret* traces back to the Latin *secretus*, derived from *secerner*, a verb denoting the act of separating, setting apart, and preserving. From this origin, the term refers to that which is deliberately withheld from exposure—not as a consequence of chance or neglect, but as the result of a conscious decision to exclude third parties. In this sense, secrecy establishes an intangible boundary between what may be communicated and what remains confined to the individual sphere. Contemporary understandings of privacy, however, increasingly shaped by technological transformation, no longer appear to be fully captured by this static logic of concealment. Rather, privacy has come to be conceptualized as a legal interest of an instrumental and transversal character, operating as a silent yet indispensable precondition for the effective exercise of other fundamental rights and freedoms (De Las Heras Vives, 2025). From this perspective, *habeas data* does not emerge as an autonomous legal interest detached from privacy, but instead as one of its most elaborated normative manifestations. It is situated within the framework of informational self-determination and translates into the individual's authority to govern the circulation, processing, and destination of personal data through which identity is objectified and operationalized within automated systems (Valls Prieto, 2016). Under this understanding, privacy ceases to function merely as a defensive guarantee against external intrusion and assumes a structurally constitutive role. It is rearticulated as a right to conscious control over the informational conditions through which the individual becomes technically present in the digital environment (González Cussac, 2022). It is precisely this dimension of privacy—marked by its foundational relevance—that has informed and shaped the most recent reforms of Title X of Book II of the Spanish Criminal Code (Sáinz-Cantero Caparrós *et al*., 2025).

Chapter I of Title X of the Spanish Criminal Code regulates a set of offences traditionally classified, in continental doctrine, under the heading of *Descubrimiento y Revelación de Secretos*. While this label reflects a consolidated doctrinal taxonomy, it lacks a direct conceptual equivalent in Anglo-American criminal law. Accordingly, and for analytical clarity, the present study approaches these provisions through the functional lens of criminal protection against unauthorized access to and dissemination of private information. This structure reflects a bifurcated model of wrongdoing, articulated through two analytically distinct stages that mirror the logic of so-called two-act offences (*delitos mutilados en dos actos*) (González Cussac, 2022). The first concerns *discovery*, understood as the unauthorized intrusion into another person's informational sphere, access to which is restricted by the data subject's will. That will determine not only which contents may be known, but also who is entitled to know them and for which legitimate purposes. The second concerns *disclosure*, consisting in the circulation of information unlawfully obtained, thereby shifting the focus of

harm from the mere act of illegitimate access to the erosion of the data subject's power of exclusion and control—core components of informational self-determination.

The differentiation among these offences is organized around their respective material objects, which reflect distinct modalities of the right to privacy. At one end lies the notion of *secrecy*, governed by a fully articulated intent to exclude third parties; at the other, *reserved data*, where the decisive element is the subject's continuing authority to control information relating to them (Sáinz-Cantero Caparrós *et al*., 2025). Within this framework fall, inter alia, offences concerning the disclosure of professional secrets and those involving unlawful intrusions into information systems. Building upon this dual axis, the legislature has progressively developed a dense set of derivative offences, evidencing an incremental intensification of criminal protection in this domain. The scheme is further complemented by provisions extending criminal liability to legal persons, as well as by common procedural rules which—given the nature and axiological weight of the protected interest—condition the initiation of proceedings upon a complaint by the injured party or the Public Prosecutor, while according to legal effect, albeit in an ambivalent manner, to the victim's pardon.

Limiting the analytical focus to the examination of the offences previously outlined, the first paragraph of Article 197(1) of the Spanish Criminal Code provides for a punitive response consisting of imprisonment for a term of one to four years and a fine of twelve to twenty-four months for any person who, with the intention of discovering secrets or infringing another's privacy and in the absence of consent, unlawfully appropriates papers, letters, electronic mail messages, or any other personal documents or effects. Within this framework, the typical conduct is conceived as a form of material appropriation directed at objects that are intended to safeguard—either by their intrinsic nature or by the informational density of their content—particularly sensitive elements of the individual's private sphere (Olmo Fernández Delgado, 2009). From this perspective, the public or private character of the secret as such is legally irrelevant. Nor is it necessary that the accessed data or information possess objective importance, substantive relevance, or any qualified value, since the harm materialises in the mere intrusion into the protected sphere in which privacy is located (Muñoz Conde, 2023). A distinct normative configuration characterises the second alternative modality of unlawful discovery, set out in the second paragraph of Article 197(1). This provision subjects to the same penalties those who, with the purpose of uncovering secrets or undermining another's privacy and without the consent of the person concerned, intercept telecommunications or make use of technical devices for listening, transmitting, recording, or reproducing sound or image, as well as any other communication signal. In this case, the interference no longer targets the object that contains or preserves private information, but rather the communicative process itself—at a stage in which words, images, or gestures have not yet crystallised and confidentiality manifests as an ongoing, transient phenomenon.

Through a legislative technique whose systematic coherence is both complex and contested, Article 197(2) extends criminal liability to conduct that, while resting on partially overlapping structural premises, centres on personal or family data of a reserved nature contained in any type of file or register, whether physical or digital, and irrespective of its public or private status. The provision encompasses situations

in which the offender gains access to, appropriates, uses, or alters such data without the requisite authorisation of the data subject or of the person responsible for the relevant files or records. The resulting infringement may affect either the individual directly concerned or third parties extraneous to the original relational context. The penalty applicable mirrors that provided for in Article 197(1), namely imprisonment for a term of one to four years and a fine of twelve to twenty-four months.

A particularly salient aspect of this provision lies in the fact that its defining element is articulated, with notable precision, through the nature of the material object upon which the typical conduct is directed. Conceived in these terms, privacy appears as ordered, systematised, and fixed—most commonly through digital or computer-based mechanisms—as if the individual's memory had been translated into a stable technical structure. When such a structure is breached, it gives rise to a novel and discreet form of exposure. From this perspective, the provision constitutes an unequivocal normative response to the growing proliferation of personal data repositories or databases, which have become increasingly pervasive in contemporary social life, as well as to the risks of intrusion, manipulation, or misuse inherent in their management (Sáinz-Cantero Caparrós *et al*., 2025). This, in turn, highlights the distinctive nature of the offence, which is structured around the individual's capacity to exercise control over personal or family information that has been collected and systematized. Such information, far from being necessarily insulated from external access, is frequently supplied by the data subject themselves for a range of purposes—legitimate at their inception, yet not thereby exempt from the risk of infringement.

As doctrinal analysis has made clear, the second specific manifestation of offences against privacy is defined by disclosure, understood not as mere unauthorized access to reserved information, but as the effective externalization of data or information which, once removed from the exclusive control of its holder, is disseminated, transferred to third parties, or otherwise made available to others, thereby entering the sphere of public cognoscibility. Accordingly, the conduct cannot be regarded as a simple extension of the initial infringement of the private sphere; rather, it incorporates an additional and autonomous element of unlawfulness. The first form of disclosure is regulated in the first paragraph of Article 197(3), which criminalizes the dissemination, revelation, or transfer to third parties of the data or facts unlawfully obtained, as well as of the images captured elements expressly linked to the conduct described in paragraphs 1 and 2 of Article 197. This form of disclosure is therefore attributable to the same individuals who, at an earlier stage, unlawfully appropriated, accessed, or otherwise became aware of the informational content in question, thus completing the progression from the initial intrusion to the definitive exposure of the private sphere. By contrast, the second paragraph of Article 197(3) addresses a different scenario, punishing those who, while aware of the illicit origin of the information and without having participated in its unlawful discovery, nonetheless engage in its disclosure. In such cases, the dissemination or transfer of the content is carried out by a person external to the original act of intrusion and is accordingly configured as an autonomous offence that complements, rather than merely extends, the offence of unlawful discovery.

Article 197(4) establishes two specific aggravating circumstances in relation to the offences of unlawful discovery and disclosure of secrets. It provides for a

custodial sentence of three to five years where the conduct described in paragraphs (1) and (2) of Article 197 is committed by persons who act as custodians or controllers of files, computer, electronic, or telematic media, archives, or registers, or where the offence is perpetrated through the unauthorized use of personal data belonging to the victim. Moreover, where the data thus obtained are subsequently disseminated, transferred, or disclosed to third parties, the legislature mandates the imposition of the penalty in its upper range.

The justification for the first aggravating hypothesis lies in the cumulative nature of the wrongdoing. The infringement of the data subject's will is compounded by the breach of the enhanced duties of custody and confidentiality that are inherent in the offender's institutional or professional position. By virtue of their role as custodian or controller, the offender assumes a specific guarantor function, entrusted with ensuring compliance with the legal limits governing the use and disposition of the data or information placed under their responsibility. The second aggravating circumstance is grounded in the unauthorized use of personal data and targets a particularly qualified form of interference with the private sphere. This form of misconduct may be understood as a functional equivalent of identity misuse or impersonation, insofar as the illicit deployment of another person's identifying data operates as a means of attacking their privacy by exploiting the appearance of legitimacy and the trust such data generate vis-à-vis third parties—for example, where a person's name or national identity document is used to obtain unlawful access to a database (Muñoz Conde, 2023).

Article 197(5) of the Spanish Criminal Code further introduces a dual aggravated modality based, first, on the heightened sensitivity of the data affected and, second, on the vulnerability of the victim. The punitive response is accordingly intensified where the conduct concerns personal data revealing ideology, religion or beliefs, health status, racial origin, or sexual life, as well as where the victim is a minor or a person with a disability requiring special protection. Article 197(6), in turn, establishes an additional aggravating circumstance linked to the profit-oriented purpose underlying the commission of any of the offences defined in Article 197. In such cases, the provision authorizes the imposition of the penalty in its upper range or, where the conduct relates to particularly sensitive data—such as those referred to in the preceding paragraph—provides for a custodial sentence of four to seven years. The profit motive referred to in Article 197(6) must be understood as the intention to obtain an economic advantage, benefit, or gain derived from the unlawful discovery or disclosure of the data or information concerned. As this element operates as a subjective component of the offence, it is irrelevant whether the anticipated advantage is ultimately realized. It is sufficient that the conduct be teleologically oriented towards that purpose (Sáinz-Cantero Caparrós *et al.*, 2025).

Finally, paragraph (7) of Article 197 reflects the legislature's acknowledgement of an emerging social phenomenon marked by the increasing prevalence of practices commonly associated with *sexting* and with what legal scholarship and public discourse have termed *revenge pornography*. These situations involve the use of the dissemination of intimate images as a retaliatory mechanism, most frequently in the aftermath of terminated intimate or sentimental relationships. The provision punishes with a custodial sentence of three months to one year, or a fine of six to twelve

months, any person who, without the authorization of the individual concerned, disseminates, discloses, or transfers to third parties images or audiovisual recordings of that individual which were obtained with their consent in a private dwelling or in any other space reasonably shielded from third-party observation, provided that such dissemination causes a serious impairment of the victim's personal privacy. This form of conduct does not readily fit within the traditional conceptual framework of offences relating to the unlawful discovery and disclosure of secrets, insofar as the capture or creation of the images or recordings takes place with the express consent of the person concerned. Criminal unlawfulness is therefore not anchored in the act of producing the audiovisual material itself, but rather in the subsequent non-consensual dissemination or disclosure, which constitutes the sole phase in which the affected individual's right to control access to their intimate sphere remains legally operative. The wrongfulness of the conduct is thus constructed exclusively around the breach of the relationship of trust that governed the initial acquisition of the images, converting material originally generated under the protection of consent into a harmful exposure of private life (Castelló Nicas, 2015).

The second paragraph, introduced by Organic Law 10/2022 of 6 September, establishes an autonomous offence punishable by a fine of one to three months, targeting those who, having received the images or audiovisual recordings referred to in the preceding paragraph, disseminate, disclose, or transfer them to third parties without the consent of the person affected. Through this provision, the legislature extends the criminal protection of privacy to a subsequent stage in the circulation of intimate content, shifting the focus of criminal wrongfulness from the original act of capture or dissemination to the non-consensual propagation carried out by third parties who, although not involved in the initial act, play a decisive role in amplifying the resulting harm. In line with this expanded protective rationale, the provision further establishes a qualified aggravating circumstance—through the imposition of the penalty in its upper range—where the conduct described above is committed by the victim's spouse or by a person who is or has been linked to the offender by a comparable intimate relationship, even in the absence of cohabitation. The punitive response is thus intensified where the violation of privacy occurs within a relational framework characterised by pre-existing trust. The same aggravation applies where the victim is a minor or a person with a disability requiring special protection, as well as where the conduct is carried out for profit, thereby evidencing a heightened legislative concern for contexts of personal vulnerability and for the economic instrumentalization of intimate material.

Following the reform introduced by Organic Law 1/2015 of 30 March, Article 197 bis(1) of the Spanish Criminal Code criminalizes unauthorized access to information systems, providing for a custodial sentence of six months to two years. The offence is committed where a person, by any means or procedure and by circumventing the security measures designed to prevent such conduct, gains access—without proper authorization or facilitates such access for another—to the whole or part of an information system, or remains within it against the will of the person entitled to exclude them. This form of conduct, commonly described as *hacking* in Anglo-American legal discourse, has given rise to incidents of relevance, in which unlawful access has extended beyond privately owned systems to include infrastructures operated by public authorities and major financial institutions, thereby placing at risk not

only system security but also the integrity of significant economic interests (Muñoz Conde, 2023). The offence encompasses two alternative forms of conduct. The first consists in unauthorized entry into an information system, with the consequent potential to access the data, information, or software that it contains or governs. The second concerns unauthorised persistence within the system and presupposes an initial access that was consented to by the person holding the legitimate right of exclusion. In this latter scenario, criminal unlawfulness arises at the moment when the system holder's will to deny continued presence is expressed, thereby transforming an originally lawful access into an illegitimate occupation of a protected digital environment. For the purposes of this provision, an "information system" is to be understood, in accordance with Article 2 of Directive 2013/40/EU, as any device or group of interconnected or functionally related devices in which one or more elements perform the automated processing of data by means of a computer program, as well as the computer data themselves that are stored, processed, retrieved, or transmitted in order to ensure the system's operation, use, protection, and maintenance.

Article 197 *bis*, second paragraph, establishes a separate offence relating to the interception of data transmissions between systems. This provision does not concern automated personal communications—which fall within the scope of Article 197—but rather transmissions occurring between devices. It criminalizes the interception, without due authorization and using technical devices or instruments, of non-public transmissions of computer data transmitted from, to, or within an information system, including the electromagnetic emissions generated by such transmissions. The penalty provided is a term of imprisonment of three months to two years or a fine of three to twelve months.

The final offence introduced by the 2015 reform within the category of crimes against privacy is codified in Article 197 *ter* of the Spanish Criminal Code. This provision criminalizes preparatory conduct by imposing a custodial sentence of six months to two years, or a fine of three to eighteen months, on any person who, without due authorization, produces, acquires for personal use, imports, or otherwise supplies to third parties instruments intended to facilitate the commission of any of the offences referred to in Article 197(1) and (2) or in Article 197 bis. The scope of the provision expressly extends to computer programs that are primarily designed or adapted for the commission of such offences, as well as to computer passwords, access codes, or other data of a comparable nature that enable total or partial access to an information system. In doing so, Article 197 *ter* anticipates criminal liability to the preparatory stage, extending penal protection to the very moment at which the technical means of unlawful interference are created or made available.

2. Neurotechnological corporate practices and the limits of Criminal Law

Having delineated the criminal-law instruments aimed at protecting privacy within the Spanish legal system, the most salient criminal-law challenge to emerge from the expansion and consolidation of the corporate neurotechnology sector concerns the difficulty of subsuming these practices within offence definitions conceived for fundamentally different factual realities. Neurotechnological activities, increas-

ingly mediated through devices durably embedded in the ordinary routines of social life, expose the limited capacity of existing criminal provisions to capture the specific characteristics of these new objects of legal protection. This normative mismatch reveals a zone of dogmatic indeterminacy in which unlawful access to, and unauthorized dissemination of, information call for a reassessment of the foundations of criminalization, with a view to determining the conditions, scope, and criteria under which such conduct should attract criminal liability. The argument developed in this chapter is structured around this problem. To that end, it draws on the judgment delivered on 9 August 2023 by the Supreme Court of Chile, not for the purpose of offering a doctrinal commentary on its reasoning, but rather as an analytical lens through which to identify and make visible factual scenarios that, until very recently largely unfamiliar, are now emerging as patterns likely to acquire regularity in the context of contemporary technological change.

For the purposes of providing an adequate contextual framework, it is necessary to recall that, in 2022, former senator Guido Girardi acquired and used *Insight*, an electroencephalography device developed by *Emotiv*, designed to capture neural signals for the interpretation of emotional states and the execution of mental commands. A particularly contentious feature of this arrangement was that user access to their own neural records was made conditional upon the acquisition of a "Pro" license; in the absence of such a subscription, the data remained stored within the company's data processing and storage systems, even following the termination of the user account. Insofar as Mr Girardi opted for the free licensing model, he was consequently denied access to the data derived from his own cerebral activity. Nevertheless, pursuant to Emotiv's privacy policies, those data remained potentially subject to disclosure to third parties. In his assessment, given the ontological specificity of neural information and the risks inherent in its processing, the possibility of re-identification, unlawful intrusion, secondary use, or transfer for purposes unrelated to the consent initially provided could not be excluded. On this basis, he challenged the company's privacy policies and sought the immediate erasure of all data relating to him. After obtaining a partially favorable decision before the Santiago Court of Appeal, he lodged an appeal before the Supreme Court. As anticipated, the appeal was ultimately upheld. The Chilean Supreme Court ordered the definitive deletion of all brain-related records associated with Mr. Girardi and, additionally, mandated that the device be subjected to comprehensive technical scrutiny by the competent customs and health authorities. Such scrutiny was established as a necessary precondition for any future authorization of the device's importation, circulation, and use within the national territory.

A careful hermeneutic reading of the judgment reveals an explicit—and, in many respects, genuinely pioneering—acknowledgement of the risks that innovations associated with wearable technologies and artificial intelligence systems pose to the legal protection of mental privacy (Wernicke *et al*., 2017). As the case illustrates with particular clarity, even devices intended for widespread and routine use already exhibit a significant capacity to infer, capture, and potentially manipulate sensitive information rooted in the individual's cognitive, emotional, and decisional domains.

When the assessment of such practices is relocated within the criminal-law framework—as methodological consistency requires—the question inevitably arises

as to whether the offence definitions traditionally applied in this field continue to offer effective protection for mental privacy. This doubt is especially acute given that their normative design reflects an informational paradigm in which data were understood primarily as an external manifestation of the person, rather than as a vector enabling direct or inferential access to the most intimate dimensions of the individual's psychic and cognitive sphere (Villanueva Tobalina, 2025).

In particular, the question arises as to whether such conduct may properly be assessed under Article 197(2) of the Spanish Criminal Code. In this respect, although, as noted above, Mr Guido Girardi initially granted the company authorization to use the device, it cannot be ruled out that such consent may subsequently have been exceeded, reinterpreted, or instrumentalized in pursuit of purposes substantially unrelated to those originally accepted. Were such a circumstance to be established, the conditions for the full applicability of the relevant criminal offence would be met, insofar as the legitimizing basis that initially authorized the processing of the data concerned would have been undermined.

This concern is further exacerbated by the breadth and ambiguity of the mechanisms currently used to obtain the data subject's consent, a factor that bears directly on the delineation and verification of the normative requirement of valid authorization under the relevant provision. Such mechanisms may include, by way of example, the simple activation of a checkbox within a digital interface, the adjustment of certain technical settings associated with the use of information-society services, or other forms of conduct that, in the given context, are liable to be construed as acceptance of the proposed processing of personal data, even where such acceptance occurs in the absence of a full and informed understanding of its actual scope (Magee *et al*., 2024). By capitalising on this interpretative flexibility, neurotechnology companies frequently fail to discharge their duty to provide clear, comprehensive, and intelligible information concerning the true extent of the processing applied to users' cognitive biometric data. This resulting informational opacity—often presented under the guise of the presumed technical neutrality of the devices and procedures employed—ultimately undermines the genuineness of the consent obtained and casts serious doubt on its substantive validity, insofar as it empties the principle of informational self-determination of meaningful content.

If the present analysis is pursued further, close attention must be paid to Article 197(4), which provides for a custodial sentence of three to five years where the offence is aggravated by the fact that it is committed by persons acting as custodians or controllers of files, computer, electronic or telematic media, archives, or registers, or where the conduct is carried out through the unauthorized use of the victim's personal data. The provision further provides an additional enhancement—by requiring the imposition of the penalty in its upper range—where the reserved data have been disseminated, transferred, or disclosed to third parties. From this standpoint, two distinct axes of dogmatic and systematic tension can be identified in its application. First, the provision is grounded in a traditional conception of the responsible subject, understood as the individual or entity that manages, safeguards, or exercises effective control over data files, media, or registers. Yet, within the factual constellation described in the Chilean judgment—characterized by chained algorithmic processes, functional outsourcing, platform interconnection, and automated decision-making—

the identification of a clearly defined center of effective control over inferred mental data becomes markedly blurred. Secondly, a further source of tension arises from the attempt to transpose the classical notion of personal data to information of a mental or cognitive nature generated by technological devices. This raises the question of whether the aggravating circumstance is fully capable of capturing the specificity of the risk at issue, or whether it instead reveals the strains inherent in a normative framework conceived to protect privacy in its traditional sense when confronted with new forms of intrusion that penetrate the most intimate and pre-reflective layers of the individual's sphere.

Finally, Article 197(5) of the Spanish Criminal Code also acquires a particular analytical salience, insofar as the legislature establishes an aggravation anchored in the heightened vulnerability of certain categories of personal data. The provision mandates the intensification of the penalty to its upper range where unlawful access, irregular processing, or illicit disclosure affects core domains of the personal sphere, thereby requiring an examination of whether cognitive biometric data may be subsumed within the concept of health status that underpins this aggravating clause.

In light of the foregoing considerations, the systematic tensions identified point to a structural insufficiency in the existing criminal-law response to the practices developed by neurotechnology companies. The current normative framework has yet to attain a level of precision and proportional adequacy commensurate with the nature, intensity, and potential scalability of the risks involved. These observations do not merely serve a descriptive function. Rather, they provide the conceptual foundation for the analysis undertaken in the following section, which seeks to formulate proposals for dogmatic and interpretative reconfiguration capable of addressing the challenges posed by these emerging phenomena.

3. Reconstructing penal responses to neurotechnological companies

In line with the analytical framework set out above, the inquiry first examines whether the existing provisions can afford adequate protection to mental privacy in the context at issue. This question arises insofar as those provisions were conceived based on an understanding of data as an external and objectifiable reality, detached from its contemporary capacity to mediate—directly or inferentially—access to the individual's psychic sphere. To this end, the analysis turns to the legal interest protected by the offences contained in Chapter I of Title X of Book II of the Spanish Criminal Code, concerning the unlawful discovery and disclosure of secrets. Regarding these provisions, there appears to be broad doctrinal agreement that the core of protection is anchored primarily in privacy, as safeguarded through the protection of reserved personal or family data. In other words, the criminal legislator seeks to protect data which, by virtue of their connection to personal identity, delineate the legal boundary of what is one's own, what is reserved, and what is legitimately shielded from external scrutiny (De Andrade, 2010).

Pursuant to Article 4 of Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April, personal data are defined as any information relating to an identified or identifiable natural person. Distinct from this notion is the category

of *reserved data*, whose delimitation finds no explicit formulation in the current non-criminal regulatory framework and is instead shaped as a construct of doctrinal and cultural origin (Sáinz-Cantero Caparrós *et al*., 2025). From this standpoint, reserved data are characterized less by their ontological features than by the qualified relationship they maintain with the individual's personal sphere, insofar as their indiscriminate exposure is incompatible with the preservation of autonomy, self-determination, and control over one's own affairs (Juanatey Dorado, 2023). They thus encompass information withdrawn from general access, either because of its close connection to privacy or because its circulation is contingent upon a prior expression of will or the existence of a legitimate authorization permitting its processing or disclosure.

This conception assumes relevance when considered in light of the notion of an identifiable natural person set out in Article 4 of Regulation (EU) 2016/679. Under that provision, a person is regarded as identifiable where they can be singled out, directly or indirectly, by means of an online identifier or by reference to one or more elements specific to their physical, physiological, genetic, psychological, economic, cultural, or social identity. From this perspective, it becomes apparent that the criminal offences of unlawful discovery and disclosure of secrets can extend their protective scope to mental privacy. Mental privacy does not constitute an autonomous or extraneous category vis-à-vis traditional privacy; rather, it represents one of its most sensitive and deeply rooted manifestations, intrinsically linked to personal identity and individual autonomy (Wajnerman-Paz, 2024). Mental states, cognitive processes, and emotional dynamics possess an objective capacity to render an individual identifiable. Accordingly, their capture, inferential extraction, or communication in the absence of legitimate authorization directly affects the protected interest underpinning these offences. In this sense, mental privacy may be understood as a qualified extension of the domain of reserved information, the criminal-law protection of which finds its justification in the rationale of offences against privacy, insofar as they are designed to preserve the individual's control over access to the most sensitive layers of their personal sphere.

Having established the foregoing, the analysis now turns to the second contested issue, namely the feasibility of subsuming under Article 197(2) of the Spanish Criminal Code conduct consisting in the appropriation, use, or modification of reserved personal or family data where such information is stored in computer, electronic, or telematic files or media managed by neurotechnology companies and linked to the routine use of wearable devices in everyday practices. This shift in focus calls for a careful assessment of the scope and adequacy of the provision. In such scenarios, the legislature adopts a scheme of punitive equivalence that extends not only to those who appropriate the data, but also to those who access them by any means, as well as to those who use or alter them to the detriment of the data subject or a third party. Legal scholarship has observed that these elements largely reproduce those already present in the first limb of the provision; nevertheless, in order to avoid interpretative overlap, it has advanced a differentiated reading of *appropriation* and *access*, whereby the former is associated with the extraction of data from their original medium, while the latter is confined to the mere viewing or reading of their content, without extraction (Valls Prieto, 2016).

By way of illustration, where a device contains reserved personal or family data, two distinct modes of intervention may be identified. The first involves the creation of a copy for subsequent autonomous processing. The second consists in the direct or indirect reading of the data for analytical purposes, without the generation of an independent duplicate. This latter form of access should not be understood as immediate inspection by a human agent, but rather as access mediated by algorithmic mechanisms—such as softbots or automated reading systems—capable of penetrating the device in which the data are stored and retrieving their content without extracting it or transferring it to a separate medium. In this context, access unfolds in two analytically distinct stages: the capture or reading of the information, and an initial functional stage that enables its potential disposition, without yet amounting to appropriation. Appropriation, by contrast, is consummated only when the actor acquires an effective form of possession or control over the informational corpus, even where such control does not necessarily take the form of tangible materiality in the classical sense (Valls Prieto, 2016).

From this perspective, the offence may be consummated either through the appropriation of the data—even in the absence of any immediate examination of their content—or through algorithmic processes that integrate the information into processing architectures designed for its correlation, classification, or systematization. Such processes constitute manifestations of the use, access to, or functional modification of previously recorded data. As a secondary effect, they may generate inferences concerning mental states or internal dispositions that render the individual identifiable. The core of the unlawfulness, however, does not reside in inference as such, but rather in the improper appropriation, use, access to, or alteration of pre-existing cognitive biometric data, insofar as these acts displace the information from the sphere of exclusive control of the data subject (Huergo Lora, 2021). In this regard, the so-called mosaic theory proves particularly instructive: the aggregation and combination of informational fragments that are initially authorized or seemingly innocuous may produce a qualitatively new meaning endowed with autonomous harmful potential, by enabling substantive reconstructions of personal identity or mental patterns without direct human cognitive apprehension (Madrid Conesa, 1984).

Conduct consisting in disclosure, revelation, or transfer to third parties materializes at a later stage within the typical sequence. Such conduct may operate either as a continuation of prior acts or autonomously, where the perpetrator does not coincide with the individual who originally obtained the information. The legislature has attributed to these forms of conduct sufficient normative weight to justify the application of the penalty in its upper range, insofar as they entail a particularly intense amplification of the impairment of privacy. This assessment acquires heightened relevance in environments governed by algorithmic systems, where the circulation of information ceases to be an isolated episode and becomes embedded in dynamics of replication, correlation, and inferential exploitation, capable of extending and deepening the intrusion into the affected individual's personal sphere.

Reference to conduct carried out through algorithmic processes does not entail any departure from the structural requirement of a human act capable of grounding criminal liability. Even within the domain of neurotechnological practices—where the materialization of the typical conduct may occur without immediate human

intervention through automated systems of reading, correlation, or inference—the basis of attribution does not dissolve into the technical autonomy of the process. Rather, it remains anchored in organizational decisions, design choices, configuration parameters, and functional tolerances attributable to natural persons situated within the corporate structure and vested with powers of supervision and control (Llonín Blasco, 2023). Accordingly, consummation is not linked to the automated execution of the process as such, but to the prior, conscious activation, configuration, or maintenance of organizational or technological arrangements that enable the displacement of reserved data from the data subject's sphere of exclusive control into unauthorized domains of processing.

Consistent with this rationale, it is noteworthy that Article 197(4)(a) of the Spanish Criminal Code provides for an aggravated form of liability where the interference originates from positions of qualified structural control, particularly when the conduct is carried out by persons entrusted with responsibility for computer, electronic, or telematic files, media, archives, or records. For these purposes, Regulation (EU) 2016/679 defines the data controller as the natural or legal person, public authority, agency, or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data, while the data processor is the entity that processes such data on behalf of the controller. Processing is understood as any operation or set of operations performed on personal data—whether or not by automated means—including collection, recording, organization, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure, or destruction.

Accordingly, automation neither displaces nor neutralises human involvement; rather, it mediates such involvement within a constellation of technical and organisational processes, thereby giving rise to a form of functional appropriation or access which, in the absence of legitimate authorisation, may activate the applicability of Article 197(2) in conjunction with Article 197(4)(a) of the Spanish Criminal Code. This line of reasoning further requires attention to Article 197 *quinquies*, a provision specifically intended to articulate the criminal liability of legal persons. Within this normative framework, where—pursuant to Article 31 *bis* of the Criminal Code—an offence is attributable to a collective entity, the law mandates the imposition of a fine ranging from six months to two years, without prejudice to the courts' power, under Article 66 *bis*, to additionally impose the sanctions set out in points (b) to (g) of Article 33(7).

This analysis therefore calls for close consideration of the dual-track system of attribution governing corporate criminal liability. On the one hand, a legal person is liable for offences committed in its name or on its behalf and for its benefit, whether direct or indirect, by its legal representatives or by those who, acting individually or as members of a corporate body, are authorized to adopt decisions within the entity or to exercise powers of organization or control. On the other hand, liability may arise where offences are committed, in the course of corporate activities and for the account and benefit—likewise direct or indirect—of the legal person, by individuals subject to the authority of the aforementioned persons, provided that the commission of the offence has been made possible by a serious breach of duties of supervision,

oversight, or control, assessed in light of the circumstances of the case. In this respect, Articles 31 *bis*(2) and 31 *bis*(4) introduce a normative basis for exemption from criminal liability, grounded in the adoption and effective implementation of organizational and management models incorporating adequate monitoring and control measures aimed at preventing offences of the same nature or significantly reducing the risk of their commission.

Nevertheless, even where the conduct examined throughout this study may be fully subsumed within the scope of Article 197(2) of the Criminal Code, the potential applicability of the aggravated offence provided for in Article 197(5) cannot be disregarded, given the particularly sensitive nature of the cognitive biometric data involved. As previously noted, that provision requires the imposition of the penalty in its upper range where the unlawfully processed or disclosed information reveals core aspects of the individual's intimate sphere, such as ideology, religion, state of health, racial origin, or sexual life. Against this background, the question necessarily arises as to whether cognitive biometric data improperly processed by neurotechnology companies may fall within the legal concept of health data, understood as a category encompassing the specially protected interests to which Article 197(5) refers.

For these purposes, Regulation (EU) 2016/679 of the European Parliament and of the Council provides that *data concerning health* encompass all data relating to the physical or mental condition of a natural person, including information derived from the provision of healthcare services, insofar as such information reveals aspects of that person's state of health. Recital 35 of the Regulation further refers to the physical or psychological condition—past, present, or future—of an individual, and includes information collected in connection with the person's registration in healthcare systems or generated during the effective provision of such services, as well as any number, symbol, or data assigned to uniquely identify the individual for health-related purposes. This category also extends to data derived from tests or examinations performed on body parts or bodily substances, together with data obtained from biological and genetic samples, and other information relating, by way of example, to the existence of diseases or disabilities, the risk of developing specific pathologies, medical history, the receipt of clinical treatments, or the physiological or biomedical condition of the data subject. These considerations apply irrespective of the source of the data, whether a healthcare professional, a hospital institution, a medical device, or an in vitro diagnostic test.

As follows from the foregoing, this delineation reveals a significant conceptual gap, insofar as it may exclude from its protective scope certain categories of data capable of being used to infer mental states and which, despite neither being obtained nor processed for medical purposes, display an intrusive potential of comparable magnitude. This categorical deficit becomes particularly apparent when the traditional analytical framework is assessed against standards recently articulated in the field of neurotechnology. In this respect, the UNESCO Recommendation on the Ethics of Neurotechnology is especially instructive. Its approach is characterized by the adoption of a comprehensive perspective that extends attention not only to neuronal data—irrespective of whether they have been obtained for medical purposes—but also to biometric data endowed with inferential capacity, thereby underscoring the

need for enhanced protection commensurate with the depth of the legal interest potentially affected by the conduct examined above.

Within this framework, paragraph 5 of the Recommendation defines *neuronal data* as qualitative and quantitative information relating to the structure, activity, and function of the nervous system, provided that such information has been obtained through the use of neurotechnology. These data thus constitute the most direct observations or measurements of the states of the nervous system, many of which exhibit a significant correlation with an individual's mental states. Under this characterization, the concept encompasses both direct recordings—such as neuronal firing or averaged bioelectrical signals captured through electroencephalography—and indirect functional indicators, including cerebral blood flow measured through functional magnetic resonance imaging or functional near-infrared spectroscopy.

As previously noted, the attribution of the status of *neuronal data* presupposes that such data are derived from the use of neurotechnology. Pursuant to paragraph 4 of the Recommendation, neurotechnology are understood as technical artefacts specifically designed for the measurement and examination of physical, chemical, and biological signals associated with both the structural architecture and the functional expression of the nervous system. These instruments enable not only the identification and recording of neural activity, but also its anticipation and monitoring, thereby contributing to the elucidation of the mechanisms underlying such activity, facilitating the identification of pathological states, and enabling the control of external devices. They further permit the implementation of real-time feedback loops, as well as the induction of stimulation or inhibition processes based on open-loop systems. This category also encompasses technical or interventional technologies that interact with the structure or functions of the nervous system with the aim of modifying its activity, including targeted modulation of neurophysiological functions and the immediate transmission of signals through acoustic, electrical, magnetic (including ultrasound-based), or optical stimulation, as paradigmatically illustrated by transcranial electrical stimulation.

At the same time, it is necessary to consider biometric data which, while only indirectly informative of neural activity, nonetheless possess a significant inferential capacity with respect to the individual's mental sphere. Even where the technologies used to obtain such data do not, *per se*, qualify as neurotechnology, their deployment to generate information capable of interpreting or anticipating mental states raises concerns of a substantively equivalent nature. This category includes, by way of non-exhaustive illustration, parameters such as heart rate used to assess levels of stress, or eye-tracking data employed to infer intentions and cognitive processes (Magee et al., 2024).

The need to articulate a coherent response to this emerging reality therefore leads to consideration of the potential inclusion of these categories of data within the scope of protection afforded by Article 197(5). Although they constitute conceptually distinct phenomena—the former being directly or indirectly linked to nervous system activity, and the latter derived from biometric parameters of a non-neuronal nature—they converge on a decisive structural feature: their capacity to reveal, reconstruct, or anticipate mental states, cognitive patterns, or psychic dispositions of the individual (Hallinan et al., 2014). It is this revelatory capacity, rather than the technical origin

of the data or their classification within a specific biomedical typology, that warrants enhanced criminal-law protection. On this basis, the express inclusion of so-called *cognitive biometric data* within the provision may be proposed, as a notion capable of systematically integrating both dimensions, insofar as an adequate legal response requires a shift from a predominantly health-centered framework towards the protection of mental privacy, understood as a structural precondition for safeguarding private life in its most intensive form.

In line with the foregoing analysis, biometric data are classified under the General Data Protection Regulation as *special categories of data*. To this end, Article 9(1) of the Regulation establishes, as a general principle, a prohibition on their processing, subject only to the exceptions expressly provided for in Article 9(2), among which the data subject's explicit consent occupies a central position. The regulatory framework further requires that the collection and use of such data be strictly confined to the specific purposes for which consent has been granted, unequivocally excluding any functional deviation or unauthorized reuse. Against this backdrop, it is appropriate to turn to the final problematic issue identified in the preceding section, namely the typical requirement that the conduct be carried out *without authorization*.

In this respect, the GDPR conceptualizes consent as a clear affirmative act through which the data subject expresses a freely given, specific, and informed agreement to the processing of their reserved data. Such consent may be expressed in writing—including by electronic means—or orally, provided that it is objectively verifiable. The Regulation further provides that, where processing is pursued for multiple purposes, explicit consent must be obtained in relation to each of them. As the analysis of the criminal offence has shown, however, the core difficulty does not lie so much in this formal requirement as in the breadth and ambiguity of the mechanisms through which consent is obtained, which tend to undermine its authenticity and raise well-founded doubts as to its material validity.

One possible response lies in strengthening the offence element through the delineation of a qualitative standard of consent that is relevant for criminal-law purposes, either by means of a positive definition or—more effectively—through the express exclusion of those manifestations that cannot be regarded as sufficient to exclude typicity. From this perspective, authorizations obtained through purely formal, implicit, or standardized mechanisms cannot be considered legally effective for the purposes of Article 197(2) where they deprive the data subject of a genuine understanding of the material, functional, or inferential scope of the processing of reserved data, including, within the context of the present study, cognitive biometric data.

Along the same lines, the GDPR specifies that, for consent to qualify as informed, the data subject must be aware, at a minimum, of the identity of the data controller and the purposes for which the data are to be processed. Consequently, acceptances grounded in residual interactions, preconfigured technical settings, or ambiguous conduct that fail to secure authentic self-determination vis-à-vis practices endowed with a high intrusive potential into personal privacy must be regarded as devoid of legal effect. Such a reconstruction would anchor the typical requirement in substantive rather than merely procedural criteria, linking criminal relevance to the material effectiveness of consent rather than to its purely formal appearance.

Concluding Reflections

The analytical inquiry undertaken demonstrates that the gradual incorporation of neurotechnological practices into corporate activity does not merely introduce novel risk scenarios, but fundamentally challenges the conceptual premises upon which the criminal-law protection of privacy has traditionally been grounded. The collection, processing, and inferential use of cognitive biometric data transcend the classical conception of data as a simple external representation of the individual and reposition it as a functional gateway to the mental sphere, with direct repercussions for personal autonomy, individual identity, and the capacity for conscious self-determination. From this perspective, the analysis confirms that the offences of unlawful discovery and disclosure of secrets retain a meaningful protective potential in relation to the contemporary forms of interference examined, provided that they are interpreted through a systematic and evolutive understanding of privacy as the protected legal interest. At the same time, this potential is accompanied by significant structural tensions. The distinctive informational density of the data at issue, the algorithmic mediation of conduct, and the organizational complexity of corporate environments strain the traditional parameters of the material object, complicate the contours of legally relevant authorization, and challenge established models of criminal attribution.

The purpose of this study has been to offer conceptual tools for addressing these tensions from a dogmatic and systematic standpoint. Its conclusions, however, do not purport to provide definitive answers, but rather to open a critical space for reflection on the adequacy and limits of Spanish criminal law in the face of emerging forms of intrusion that are still in the process of normative and jurisprudential consolidation. Ultimately, the decisive question is not whether criminal law can keep pace with technological innovation, but whether it remains capable of protecting that inner domain whose exposure irreversibly transforms intimacy into availability.

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Governing neurotechnology in the age of corporate cognitive power: neural data, labor governance, and the rise of neurorights

ALINE PASSOS MAIA[1]

LARISSA MACIEL DO AMARAL[2]

RAQUEL PASSOS MAIA[3]

Introduction

The rapid development and commercialization of neurotechnology have generated regulatory challenges for which existing legal frameworks were neither conceptually designed nor institutionally prepared. Once largely confined to clinical

[1] Professor of Law at the Center of Legal Sciences of the University of Fortaleza (Brazil). PhD in Labor Law from the University of Salamanca, Spain. Master's degree in Labor Law from the University of Salamanca, Spain. alinepmaia@unifor.br

[2] Professor at the University of Fortaleza and Christus University Center (Brazil). Master in law from the Federal University of Ceará. PhD in Business Administration from the University of Fortaleza. Lawyer at Rabb Carvalho Advocacia. larissaamaral@unifor.br

[3] PhD candidate in Law at the Faculty of Law of the University of Lisbon (Portugal). Master in Constitutional Law at the Faculty of Law of the University of Lisbon. Scholarship holder of the Foundation for Science and Technology-FCT. raquelpmaia13@gmail.com

and research contexts, neurotechnological applications have progressively migrated into consumer markets, workplaces, educational environments, and organizational governance systems. Devices capable of monitoring neural activity, inferring cognitive states, or subtly modulating mental processes are increasingly marketed under narratives of efficiency, safety, well-being, and performance optimization. This expansion, however, has significantly outpaced the evolution of legal and institutional safeguards designed to protect the cognitive domain.

Conventional regulatory approaches have tended to address neurotechnology through fragmented doctrinal lenses, including data protection law, medical device regulation, and general consumer safety standards. While these frameworks offer partial and sector-specific protections, they remain structurally inadequate to confront technologies that enable access to internal mental processes. Neural data differ qualitatively, not merely quantitatively, from other categories of personal or biometric information. They are directly linked to mental states that underpin identity, autonomy, agency, and self-determination. Accordingly, the risks posed by neurotechnology cannot be fully addressed through governance models designed primarily to safeguard informational privacy or bodily integrity.

This chapter argues that the regulation of neurotechnology requires a normative shift beyond data-centric and consent-based paradigms toward a neurorights-oriented framework. Neurorights have emerged in response to the growing recognition that mental privacy, cognitive autonomy, and psychological integrity constitute particularly vulnerable dimensions of human dignity in technologically mediated societies. In market-driven contexts, where economic incentives increasingly promote cognitive extraction and behavioral optimization, such vulnerabilities become especially pronounced (Maia, Amaral & Maia, 2025). Neurorights therefore function not merely as symbolic aspirations, but as a necessary legal response to the expanding reach of corporate power into cognitive processes.

The regulatory lag surrounding neurotechnology is particularly pronounced in corporate and employment settings. In these environments, neurotechnological tools are frequently integrated into systems of algorithmic management, productivity surveillance, and risk profiling. Even when framed as instruments of care, safety, or efficiency, such technologies risk deepening existing power asymmetries between employers and workers by extending managerial oversight into the cognitive and emotional dimensions of labor. Consent-based governance models, central to contemporary data protection regimes, offer limited protection in labor relations characterized by economic dependency and structurally constrained bargaining power. This context raises fundamental questions regarding the limits of contractual autonomy, the sufficiency of corporate compliance architectures, and the role of collective institutions in safeguarding mental autonomy. In this sense, this chapter advances the debate by situating neurorights within corporate governance and labor regulation, rather than treating them solely as abstract human rights claims.

Methodologically, this chapter combines normative legal analysis with a systematic narrative review of interdisciplinary scholarship published between 2018 and 2025. Drawing on contributions from law, neuroethics, philosophy, labor studies, and governance research, it maps the state of the art in neurotechnology and neurorights, critically examines the implications of corporate power and compliance dynamics,

and evaluates emerging regulatory responses. By situating neurorights at the intersection of human rights law, labor regulation, and corporate accountability, the chapter seeks to advance governance models capable of addressing the distinctive vulnerabilities of the human mind within contemporary political economies.

1. Methodological note: systematic literature review (2018–2025)

This chapter is grounded in a systematic narrative review of the academic literature on neurotechnology, neurorights, and rights-based governance. Although the analysis adopts a normative legal perspective, the review was conducted in accordance with internationally recognized methodological standards commonly applied in interdisciplinary legal, ethical, and governance research. The objective was not statistical aggregation, but critical mapping of theoretical positions, conceptual developments, and regulatory responses relevant to the governance of neurotechnology.

The literature search focused on peer-reviewed publications indexed in major academic databases, including Web of Science, Scopus, PubMed, and Google Scholar. These databases were selected to ensure broad disciplinary coverage, capturing contributions from law, neuroscience, neuroethics, philosophy, labor studies, and science and technology studies. Complementary searches were conducted in specialized journals and edited volumes addressing emerging technologies, human rights, corporate governance, and labor regulation, allowing for the inclusion of both foundational works and recent critical developments.

Search strategies combined keywords related to neurotechnology and rights-based regulation. Core search terms included "neurorights," "neuro-rights," "mental privacy," "cognitive liberty," "mental integrity," "neural data," "brain–computer interface," "BCI," "EEG," "consumer neurotechnology," "workplace monitoring," "algorithmic management," "corporate governance," "human rights," and "compliance." Boolean operators were employed to refine the results and enhance thematic precision across databases.

The temporal scope of the review was defined as 2018 to 2025. This period corresponds to the consolidation of neurorights as a distinct conceptual framework, the expansion of non-medical and corporate applications of neurotechnology, and the emergence of institutional and regulatory responses at national and international levels. Publications in English, Portuguese, and Spanish were included, reflecting the transnational nature of the debate and enabling the integration of European, Latin American, and Anglo-American scholarship.

Inclusion criteria prioritized peer-reviewed journal articles, scholarly books, and book chapters with full-text availability and direct relevance to neurotechnology governance, labor relations, and fundamental rights. Exclusion criteria encompassed non-validated grey literature, duplicated records, texts without access to complete content, and publications lacking sufficient methodological transparency or normative rigor. Rather than pursuing a quantitative meta-analysis, the review adopted a qualitative synthesis approach, identifying recurring themes, conceptual tensions, and regulatory proposals across the literature.

This methodological strategy is consistent with the aims of normative legal research, which emphasizes interpretive analysis and conceptual coherence over quan-

titative measurement. By systematically mapping the literature, the chapter situates its normative claims within the broader state of the art and provides a grounded basis for examining corporate power, compliance mechanisms, and the evolving role of neurorights in contemporary governance models.

2. State of the art on neurotechnology and neurorights (2018–2025)

Since 2018, neurorights have emerged as a distinct and rapidly consolidating field of interdisciplinary inquiry, reflecting growing concern over the legal and ethical implications of neurotechnology beyond clinical contexts. Contemporary scholarship has moved from speculative reflections on brain–computer interfaces to more concrete analyses of regulatory design, corporate deployment, and governance frameworks. The state of the art is therefore marked by both conceptual innovation and increasing attention to the structural conditions under which cognitive risks materialize, particularly in corporate and employment settings. This section critically maps the principal thematic developments shaping current debates, highlighting key conceptual tensions and regulatory trajectories that inform the evolving architecture of neurorights governance.

2.1. Neurotechnology and the transformation of cognitive vulnerability

Recent research has converged on the understanding that neurotechnology reshapes traditional notions of vulnerability by relocating the locus of risk from external behavior to internal cognitive processes. Unlike earlier digital technologies, which primarily enabled surveillance of actions or interactions, neurotechnological systems operate at the level of neural activity itself, opening pathways to access, infer, and potentially influence mental states that were previously inaccessible to technological mediation.

Since 2018, the literature has increasingly emphasized that the risks associated with neurotechnology are qualitatively distinct from those posed by other forms of data-driven innovation (Ienca and Andorno, 2017; Farahany, 2023; Rainey, 2024). Neural data are not merely sensitive information; they are constitutively linked to cognition, emotion, intention, and identity. This shift marks a transition from informational vulnerability to cognitive vulnerability, in which the object of governance is no longer what individuals do, but how they think and feel (Ienca, 2021; Lavazza and Giorgi, 2023; Danaher, 2021; Yuste et al., 2017).

This transformation carries significant regulatory implications. Neurotechnologies capable of monitoring attentional patterns, emotional responses, or cognitive load challenge foundational assumptions underlying consent-based governance models (Bublitz, 2016; Farahany, 2023). Neural signals may be generated continuously and involuntarily, often without the individual's full awareness of what aspects of mental life are being accessed or inferred. As a result, traditional mechanisms of notice and consent offer limited protection against cognitive intrusion.

The literature further highlights that cognitive vulnerability is amplified in market-oriented environments characterized by structural power asymmetries. In workplaces, neurotechnological tools are increasingly integrated into productivity monitoring, safety management, and performance optimization systems.

Within such contexts, workers face constrained opportunities to refuse participation without adverse consequences, rendering consent largely formal rather than substantive. Cognitive vulnerability thus emerges not only as a technological condition, but as a socio-economic one shaped by organizational power relations.

Against this background, scholars argue that effective governance must explicitly recognize the mental sphere as a protected domain. Cognitive vulnerability has become a foundational concept in the development of neurorights, framing the need for legal safeguards capable of addressing risks that extend beyond data misuse to encompass unjustified cognitive inference and manipulation.

2.2. From brain data to mental states: conceptual disputes in the literature

A central conceptual debate in the governance of neurotechnology concerns the relationship between brain data and mental states. Early regulatory discussions frequently approached neurotechnological risks through analogies with genetic or biometric data, emphasizing concerns related to data protection, security, and ownership. More recent scholarship, however, has increasingly questioned the adequacy of this data-centric framing.

Several authors emphasize that brain data cannot be understood as neutral or passive information (Ienca, 2021; Brown, 2024). When processed through neuroscientific models and machine-learning systems, neural signals are transformed into inferences about cognitive traits, emotional dispositions, attentional capacity, or behavioral tendencies. It is this inferential process—rather than the mere collection of raw neural signals—that generates the most significant normative concerns. Control over interpretive frameworks confers epistemic authority, often without transparency or meaningful ways for contestation (Lavazza and Giorgi, 2023; Rainey, 2024; Zuboff, 2019; Mittelstadt, 2019). This shift transforms corporate actors into epistemic authorities over workers' mental states, a role traditionally reserved for clinical, therapeutic, or judicial contexts.

The literature identifies a growing tension between two regulatory approaches. One position maintains that extending existing data-protection regimes to explicitly include neural data may suffice to address emerging risks. From this perspective, strengthened safeguards concerning consent, purpose limitation, and data security could mitigate potential harms. A competing position argues that such an approach remains fundamentally inadequate, as it regulates informational inputs while leaving largely unaddressed the interpretive outputs that directly shape individuals' opportunities and autonomy (Ienca and Andorno, 2017; Brown, 2024).

This distinction is particularly salient in corporate and employment contexts. When neural data are used to infer mental states related to attention, stress, or emotional engagement, the resulting classifications may inform managerial decisions concerning productivity, suitability, or employability. In these cases, harm does not stem solely from data misuse, but from the normalization of cognitive profiling as a legitimate basis for organizational control. The literature thus increasingly advocates a shift in regulatory focus from brain data to mental states, aligning governance frameworks with the normative foundations of neurorights.

2.3. Neurorights: emergence, definitions, and critical developments

Neurorights emerged in the academic literature as a response to the recognition that existing human rights frameworks were not fully equipped to address the risks posed by neurotechnology. Early formulations articulated neurorights in relatively abstract terms, emphasizing cognitive liberty, mental privacy, and psychological continuity. Post-2018 scholarship, however, increasingly situates these rights within concrete socio-economic contexts marked by asymmetric power relations, particularly in workplaces and corporate environments (Farahany, 2023; Ajunwa, 2020).

A defining feature of this evolution is the shift from therapeutic to non-medical applications. While clinical uses of neurotechnology are generally governed by established medical ethics and regulatory oversight, corporate deployments often operate in regulatory grey zones.

Neurotechnologies marketed for fatigue detection, attention monitoring, or emotional engagement are framed as tools for enhancing efficiency, safety, or well-being. Yet the literature consistently warns that such applications blur the boundary between occupational health and managerial surveillance (Ajunwa, 2020; De Stefano, 2022).

Critical scholarship further challenges the reliance on consent as a legitimizing mechanism. In labor relations, consent is structurally constrained by economic dependence and organizational hierarchies. This dynamic has been described as a form of "consensual asymmetry," in which formal agreement masks underlying power imbalances (Bublitz, 2016; De Stefano, 2022). Within this context, neurorights are increasingly conceptualized not merely as individual entitlements, but as structural constraints on corporate authority over cognitive processes.

This reconceptualization marks a maturation of the neurorights discourse. Rather than remaining confined to speculative ethical debate, neurorights are increasingly framed as legal instruments capable of addressing concrete governance challenges arising from the commodification of cognition in contemporary economies.

2.4. Neurorights as new rights or as evolutive extensions of existing rights

A recurring theoretical question concerns whether neurorights should be understood as entirely new human rights or as evolutive reinterpretations of existing rights. One strand of scholarship argues that the unprecedented capacity of neurotechnologies to access and influence mental processes justifies the recognition of a novel category of rights tailored to the cognitive domain (Ienca and Andorno, 2017; Farahany, 2023). From this perspective, traditional rights such as privacy or freedom of thought were not formulated with neural inference technologies in mind and therefore require supplementation.

An alternative position emphasizes continuity rather than rupture. Proponents of this view argue that neurorights can be grounded in long-standing protections of human dignity, personal integrity, and freedom of thought, functioning as contextual specifications rather than entirely new rights (Lavazza and Giorgi, 2023; Brown,

2024). This approach is often favored for its potential to enhance legal coherence and enforceability, particularly within labor law and corporate regulation.

Increasingly, the literature adopts a hybrid position that bridges these perspectives. Neurorights are understood as evolutive extensions of existing rights, recalibrated to address the specific risks introduced by neurotechnology. (Lavazza & Giorgi, 2023; Rainey, 2024)

This synthesis is especially relevant in employment contexts, where embedding neurorights within established legal frameworks—such as occupational health and safety law, limits on workplace surveillance, and anti-discrimination protections—enhances their practical effectiveness.

From a governance standpoint, this hybrid approach reinforces a critical normative claim: regardless of their formal classification, neurorights must function as non-waivable constraints on corporate practices that seek to optimize productivity through cognitive monitoring or inference. In this sense, neurorights articulate a boundary between legitimate organizational management and impermissible intrusion into the mental sphere of work.

3. Corporate neurotechnology and power asymmetries

Corporate neurotechnology may be understood as a form of cognitive extractivism, in which neural signals are transformed into economic value within managerial infrastructures (Zuboff, 2019; Ajunwa, 2020).The integration of neurotechnology into corporate environments represents a significant reconfiguration of the relationship between technology, labor, and power. While early neurotechnological developments were largely restricted to clinical and research settings, recent years have witnessed the rapid expansion of non-medical neurotechnologies marketed for productivity enhancement, workforce optimization, safety management, and employee well-being. This expansion has occurred primarily within organizational contexts characterized by asymmetric power relations, intensifying longstanding inequalities between employers and workers.

The literature consistently emphasizes that corporate neurotechnology is embedded within managerial and economic rationalities that prioritize efficiency, performance, and risk reduction. Even when framed as tools for care or wellness, neurotechnological systems are typically integrated into broader infrastructures of algorithmic management. In these environments, neural data and cognitive inferences become inputs for decision-making processes related to task allocation, performance evaluation, and behavioral regulation. As a result, neurotechnology does not merely observe work processes; it actively reshapes them.

A central concern identified in the post-2018 literature is the opacity of corporate neurotechnological systems. Many neurotechnology companies rely on proprietary algorithms, trade secrecy protections, and complex machine-learning models that obscure how neural data are processed and translated into actionable outputs. This lack of transparency limits workers' capacity to understand, contest, or challenge the cognitive assessments that may affect their employment conditions. Scholars warn that such opacity undermines procedural fairness and exacerbates informational asymmetries in already unequal labor relationships.

Power asymmetries are further reinforced by the limitations of consent-based governance models in employment contexts. Even where participation in neurotechnological monitoring is formally voluntary, economic dependency and organizational pressure significantly constrain workers' ability to refuse. The literature highlights that refusal may be perceived as non-cooperation or lack of commitment, creating implicit incentives for compliance. Consequently, consent operates less as an expression of autonomous choice and more as a mechanism for legitimizing intrusive practices.

Another dimension of corporate power emerges through the commodification of neural data generated in workplace settings. Neurotechnology enables the aggregation and analysis of cognitive information at scale, transforming neural signals into organizational assets. These data may be repurposed beyond immediate workplace objectives, including for product development, predictive analytics, or integration into broader data ecosystems. Such practices raise complex questions regarding purpose limitation, data ownership, and the long-term consequences of constructing cognitive profiles linked to employability or productivity.

The literature also underscores the intersectional risks associated with corporate neurotechnology. Neural metrics and cognitive classifications may reproduce or amplify existing biases related to gender, race, disability, or mental health, particularly when normative assumptions about productivity and emotional regulation are embedded in algorithmic models. In this sense, neurotechnology risks becoming a new vector of discrimination under the guise of scientific objectivity. Scholars therefore argue that neurorights must be articulated in conjunction with anti-discrimination and labor-protection frameworks to address these compounded harms.

From a governance perspective, corporate neurotechnology occupies a hybrid regulatory space that challenges traditional legal classifications. It intersects with occupational health and safety, data protection, algorithmic governance, and human rights law, yet fits neatly into none of these categories. The literature increasingly calls for regulatory approaches that recognize this hybridity and impose substantive limits on the deployment of neurotechnology in employment contexts, particularly where cognitive monitoring or inference affects workers' rights and livelihoods.

Ultimately, the corporate use of neurotechnology reveals a structural tension between market rationality and mental self-determination. While employers may justify neurotechnological tools as instruments of optimization or care, their deployment risks transforming cognition into a site of managerial extraction and control.

In response, the literature positions neurorights as a necessary counterbalance to corporate power, capable of delineating non-negotiable boundaries around the mental dimension of work and reaffirming the primacy of human dignity in technologically mediated labor relations.

4. Regulatory responses and governance models: compliance, collective action, and accountability

Before examining specific governance instruments, it is necessary to clarify the regulatory landscape within which neurotechnology currently operates. The governance of corporate neurotechnology does not emerge in a normative vacuum; rather, it develops at the intersection of soft law initiatives, sectoral regulatory regimes, and

fragmented national approaches. This regulatory pluralism reflects both the novelty of the technology and the difficulty of classifying neurotechnological risks within existing legal categories. As a result, governance responses have evolved unevenly, combining voluntary standards, constitutional experimentation, and corporate compliance strategies. The following subsections examine these emerging models and assess their capacity to translate neurorights into enforceable constraints on corporate power.

4.1. Soft law and emerging governance frameworks

In the absence of comprehensive and binding regulation, soft law instruments have played a central role in shaping early governance responses to neurotechnology. International organizations have increasingly acknowledged that neurotechnological applications raise risks that extend beyond conventional data protection and biomedical ethics, calling for regulatory approaches grounded in human dignity, precaution, and proportionality.

Normative initiatives developed by international bodies have provided an initial architecture for addressing these challenges. UNESCO's work on the ethics of artificial intelligence and emerging technologies has articulated principles directly relevant to neurotechnology, including respect for mental autonomy, transparency, and accountability. Similarly, the OECD Recommendation on Responsible Innovation in Neurotechnology proposes a lifecycle-based governance model encompassing research, development, commercialization, and post-market oversight. Although non-binding, these instruments exert significant normative influence on states and corporate actors operating in transnational markets (UNESCO, 2021; OECD, 2019).

From a corporate perspective, soft law has become a key reference point for compliance and risk management strategies. Multinational companies increasingly internalize international ethical standards through codes of conduct, internal policies, and compliance programs, particularly in areas characterized by regulatory uncertainty. In the context of neurotechnology, soft law principles are frequently invoked to justify internal safeguards related to transparency, human-rights impact assessment, and oversight of cognitive monitoring practices.

At the same time, the literature consistently warns against overreliance on voluntary governance mechanisms. Without enforceability and meaningful worker participation, soft law risks functioning as symbolic compliance rather than substantive protection. This limitation is especially pronounced in employment contexts, where structural power asymmetries constrain individuals' ability to contest corporate practices.

As a result, scholars emphasize that soft law must be complemented by binding regulation and collective governance mechanisms to ensure effective protection against cognitive exploitation.

4.2. Hard law developments: Chile, Spain, and the limits of individualized protection

Recent hard law initiatives illustrate both the promise and the limitations of neurorights-oriented regulation. Chile's constitutional reform recognizing mental integrity and establishing protections concerning neurotechnologies represents a

landmark development, signaling formal acknowledgment of the mind as an object of constitutional concern. Spain's Charter of Digital Rights similarly articulates protections related to mental privacy and cognitive autonomy within a broader digital rights framework.

While these initiatives are widely regarded as pioneering, the literature adopts a cautious assessment of their practical impact on corporate and employment practices. Constitutional recognition and policy declarations, though symbolically powerful, do not automatically translate into enforceable obligations for employers or neurotechnology companies. Without detailed implementing legislation, labor-specific provisions, and institutional enforcement mechanisms, neurorights risk remaining abstract guarantees with limited operational effect.

Moreover, scholars note that hard law approaches centered on individualized rights may inadequately address collective and systemic dimensions of cognitive harm. Workplace neurotechnology often affects groups of workers simultaneously, reshaping organizational norms and expectations. Individual remedies may therefore fail to capture the structural nature of these risks, underscoring the need to complement individual rights with collective and institutional safeguards.

4.3. Corporate compliance and the operationalization of neurorights

The literature increasingly identifies corporate compliance as the primary site where neurorights must be translated from normative principles into concrete organizational practices. Compliance frameworks shape how neurotechnology is selected, deployed, monitored, and audited within firms, making them central to the practical effectiveness of neurorights-based governance.

A first operational dimension concerns internal risk assessment and classification of neurotechnological uses. Scholars argue that companies should adopt risk-based taxonomies distinguishing between low-, medium-, and high-risk applications, with heightened safeguards applied to technologies involving continuous neural monitoring, cognitive inference, or behavioral modulation.

This approach allows neurorights considerations to be integrated into existing compliance infrastructures, such as data protection impact assessments and occupational health and safety protocols (OECD, 2019).

A second dimension involves human rights due diligence. Drawing on the UN Guiding Principles on Business and Human Rights, the literature emphasizes that neurotechnology-related due diligence must extend beyond informational privacy to encompass impacts on cognitive autonomy, mental integrity, and psychological well-being. In practical terms, this requires assessing proportionality, identifying less intrusive alternatives, and evaluating the potential for discriminatory or stigmatizing outcomes.

Auditability and oversight constitute a third critical compliance challenge. Scholars stress that companies cannot rely solely on vendor assurances or proprietary secrecy when deploying neurotechnologies that affect workers' cognitive sphere. Minimum standards of auditability—including documentation of inference models, independent validation of neurotechnological claims, and mechanisms enabling affected individuals or their representatives to contest outcomes—are identified as es-

sential to preventing arbitrary or scientifically unfounded decision-making (Brown, 2024).

Finally, the literature highlights the importance of establishing non-waivable internal standards. In employment contexts, certain neurorights-based protections cannot be overridden by individual consent, even when formally documented.

Embedding non-waivable safeguards into internal policies—such as prohibitions on using neural metrics for disciplinary action or performance ranking—aligns corporate compliance with the structural realities of labor relations and reduces exposure to legal and reputational risks.

4.4. Trade unions and collective bargaining as governance mechanisms

Trade unions emerge in the literature as indispensable actors in the governance of workplace neurotechnology. Unlike individualized consent-based models, collective bargaining provides a structural mechanism for rebalancing power asymmetries between employers and workers. Scholars emphasize that unions are uniquely positioned to negotiate limits on neurotechnological monitoring, establish transparency requirements, and secure safeguards against discriminatory or punitive uses of cognitive data (De Stefano, 2022; Ajunwa, 2020).

Collective agreements can operationalize neurorights within specific organizational contexts by restricting permissible uses of neurotechnology, mandating independent oversight, and ensuring worker participation in decision-making processes. Unions may also play a preventative role by engaging early in discussions about technological adoption, influencing organizational choices before intrusive practices become normalized.

By embedding neurorights within collective labor institutions, governance models move beyond individualized protection and address the systemic nature of cognitive risks. This collective dimension is increasingly recognized as essential to the effective enforcement of neurorights in employment settings.

4.5. Regulatory fragmentation and the need for integrated governance

Despite these emerging governance mechanisms, the literature identifies regulatory fragmentation as a persistent challenge. Divergent national approaches and uneven enforcement create opportunities for regulatory arbitrage by neurotechnology companies operating transnationally.

This fragmentation is particularly problematic in global supply chains and platform-based work environments, where workers may be subject to cognitive monitoring without clear jurisdictional oversight.

Scholars therefore advocate for integrated governance models that align international norms, corporate compliance obligations, and labor protections. Such models aim to ensure that neurorights function as effective constraints on corporate power across borders, rather than as symbolic commitments confined to specific legal systems.

In this sense, the governance of neurotechnology becomes inseparable from broader debates on transnational regulation, corporate accountability, and the protection of human dignity in technologically mediated economies.

5. Research gaps and emerging trends (2018–2025)

Despite the growing body of scholarship on neurotechnology and neurorights, the literature reveals significant gaps that limit both theoretical consolidation and regulatory effectiveness. These gaps are particularly evident in corporate and employment contexts, where neurotechnological practices are advancing more rapidly than the legal and institutional mechanisms designed to govern them. Identifying such shortcomings is essential not only for academic development, but also for informing future regulatory, compliance, and collective governance strategies.

A first and particularly salient gap concerns the limited availability of empirical research on the actual deployment of neurotechnology within workplaces. While conceptual and normative analyses have expanded considerably since 2018, relatively few studies examine how neurotechnological tools are implemented in organizational settings, how neural data are operationalized in managerial decision-making, or how workers experience and interpret cognitive monitoring practices.

This lack of empirical grounding restricts the ability of regulators, compliance professionals, and trade unions to assess the real-world implications of neurotechnology for cognitive autonomy, mental health, and equality at work.

A second gap relates to the operationalization of accountability and auditability in neurotechnological systems. Although transparency, explainability, and oversight are recurrent themes in governance frameworks, the literature offers limited guidance on how these principles can be meaningfully applied in contexts characterized by proprietary algorithms and trade secrecy protections.

As a result, companies may deploy neurotechnological tools without effective external or internal scrutiny, shielding cognitive inference processes from challenge. Emerging scholarship suggests that future research should focus on developing minimum auditability standards tailored specifically to neurotechnology, balancing intellectual property interests with the protection of fundamental rights.

The integration of neurorights into labor law constitutes a third major gap. Much of the existing literature approaches neurorights from a general human rights perspective, often overlooking the doctrinal tools and enforcement mechanisms available within labor and employment law.

Questions regarding the relationship between neurorights and occupational health and safety obligations, limits on workplace surveillance, and anti-discrimination protections remain underexplored. Given that workplaces represent one of the primary sites of non-medical neurotechnology deployment, this omission significantly weakens current governance models.

A fourth gap concerns the collective dimension of neurorights enforcement. While individual rights-based approaches dominate existing regulatory frameworks, cognitive harms frequently arise from systemic organizational practices rather than isolated incidents. Trade unions and collective bargaining institutions are increasingly identified as potential co-regulators capable of translating neurorights into enforceable workplace norms. However, empirical and doctrinal analyses of union engagement with neurotechnology governance remain scarce. Research examining collective agreements, sectoral standards, and union-led monitoring mechanisms represents an important emerging agenda.

Finally, the literature points to emerging trends linking neurorights to corporate governance, ESG frameworks, and responsible business conduct. Investors, regulators, and civil society actors are beginning to scrutinize how companies manage risks related to mental health, cognitive autonomy, and algorithmic control.

This trend suggests that neurorights may increasingly function as indicators of corporate responsibility and long-term risk management. At the same time, scholars caution that without binding obligations and effective enforcement, the incorporation of neurorights into ESG narratives risks becoming performative. Future research must therefore critically assess whether ESG-oriented governance can deliver substantive cognitive protections or merely reframe existing power asymmetries in ethical terms.

Taken together, these gaps and emerging trends highlight the need for interdisciplinary research capable of bridging normative theory, empirical analysis, and regulatory design. As neurotechnology continues to evolve, the development of effective governance models will depend on sustained engagement with the structural conditions under which cognitive risks arise, particularly in corporate and employment settings.

Conclusion

The rapid expansion of neurotechnology signals a qualitative transformation in the relationship between technology, power, and the human mind. As this chapter has argued, neurotechnological systems challenge foundational assumptions embedded in existing legal and regulatory frameworks by enabling unprecedented access to cognitive processes that were previously shielded from technological mediation. In market-oriented environments—particularly in workplaces—these technologies risk converting cognition itself into an object of extraction, optimization, and control, thereby deepening structural asymmetries between corporate actors and individuals.

What is at stake is not merely the protection of sensitive information, but the preservation of mental self-determination within organizational contexts increasingly shaped by algorithmic governance and performance rationalization.

The systematic narrative review conducted in this chapter demonstrates that governance models centered on data protection, medical-device regulation, and individualized consent are structurally insufficient to address the specific risks posed by neurotechnology. Neural data and cognitive inferences implicate dimensions of mental life that cannot be adequately safeguarded through informational paradigms alone. The emergence of neurorights reflects a growing recognition that mental privacy, cognitive autonomy, and psychological integrity constitute vulnerable dimensions of human dignity requiring explicit legal and institutional protection.

Crucially, this analysis underscores that neurorights cannot remain abstract ethical aspirations detached from organizational realities; their normative force depends on their capacity to operate as concrete constraints on corporate power when translated into compliance mechanisms, human rights due diligence processes, and internal governance structures.

At the same time, the chapter highlights the limitations of purely individualistic approaches. In employment contexts characterized by economic dependency and hi-

erarchical control, consent-based governance fails to provide meaningful protection, reinforcing the need for non-waivable safeguards grounded in fundamental rights. Trade unions and collective bargaining institutions therefore emerge as central actors within this governance landscape. By enabling the collective negotiation of limits on neurotechnological deployment, transparency obligations, and oversight mechanisms, unions provide a structural counterweight to corporate power and a practical means of translating neurorights into enforceable workplace norms. This collective dimension is essential to addressing systemic cognitive risks that cannot be effectively remedied through individualized legal claims.

At the regulatory level, recent developments—ranging from soft law instruments to pioneering national initiatives—signal important progress while simultaneously exposing the risks of fragmentation and regulatory arbitrage. In the absence of coordinated standards and effective enforcement across jurisdictions, neurotechnology companies may exploit regulatory gaps, externalizing cognitive risks to vulnerable populations.

This reality reinforces the need for integrated governance models capable of aligning international norms, corporate compliance obligations, and labor protections. Ultimately, regulating neurotechnology requires a paradigmatic shift in legal reasoning: from treating cognition as a source of data to recognizing it as a protected domain of human dignity. Neurorights provide a normative framework capable of articulating this shift, but their effectiveness will depend on their translation into concrete legal, institutional, and organizational practices.

By situating neurorights at the intersection of human rights, labor law, and corporate accountability, this chapter contends that the future of neurotechnology governance must remain rights-centered, structurally attentive to power asymmetries, and institutionally grounded in enforceable protections for the cognitive dimension of human agency.

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Algorithmic discrimination based on gender in the context of the labor market and companies: a dialogue on just transition and employability

DENISE ALMEIDA DE ANDRADE[1]

MONICA SAPUCAIA MACHADO[2]

THAMMY ISLAMY CARLOS BRITO[3]

Introduction

The historical evolution of social organization has been shaped by narratives that consistently marginalize women's experiences. Patriarchal power structures

[1] Holds a Ph.D. and a Master's degree in Constitutional Law. She completed postdoctoral research in Political and Economic Law and is currently a postdoctoral researcher in Law at the Faculty of Law of the Federal University of Ceará (UFC), funded by CAPES. She is a Professor in both the LL.M. program and the undergraduate Law program at Universidade Christus and a Professor at FGVLaw São Paulo. She is also Co-Coordinator of the CNPq Research Group *Women and Democracy*. Email: andradedenise@hotmail.com

[2] Holds a Ph.D. and a Master's degree in Political and Economic Law from Universidade Presbiteriana Mackenzie, with her degrees formally recognized by Universidade Nova de Lisboa. She also holds a postgraduate degree in Public Administration from Fundação Getulio Vargas and a Bachelor of Laws (LL.B.) from Pontifícia Universidade Católica do Rio de Janeiro. She is a tenured Professor and Program Director of the Professional Master's Program in Law at the Brazilian Institute of Education, Development and Research (IDP). She serves as Co-Leader of the CNPq Research Group *Women, Income, and Democracy*, conducting interdisciplinary research at the intersection of gender equality, public policy, technological transformation, and social justice. Email: monica.machado@idp.edu.br

[3] Is a Ph.D. candidate and holds a Master's degree in Law, Access to Justice, and Development from Universidade Christus. She is currently pursuing a postgraduate specialization in Corporate Compliance and Integrity at Pontifícia Universidade Católica de Minas Gerais (PUC Minas). She also holds a specialization in Public Administration from PUC Minas, a specialization in Law, Technology, and Innovation in Data Protection from Universidade de Fortaleza (UNIFOR), and a specialization in Public Law with an emphasis on Public Management from Faculdade Damásio de Jesus. Email: thammybritto@hotmail.com.

have established gendered hierarchies, positioning men as the default standard of humanity and relegating women's experiences to deviations from this norm. This structural asymmetry has profoundly influenced the organization of work, access to opportunities, and the recognition of labor, resulting in enduring inequalities that persist in contemporary labor markets. Therefore, gender inequality must be understood as a fundamental characteristic of economic and social structures, not merely as an incidental byproduct.

Technological advancement has failed to eradicate these historical asymmetries. Rather, the ongoing digital transformation has introduced additional mechanisms that perpetuate and, in some instances, exacerbate entrenched gender inequalities. The widespread integration of artificial intelligence (AI) systems into workplace organization, recruitment, performance evaluation, and management has transformed labor relations in ways that are not socially or legally neutral. While technological innovation offers potential improvements in efficiency and productivity, its intersection with pre-existing gendered divisions of labor raises substantial concerns regarding unequal access, representation, and recognition within the workforce.

Within this evolving context, women's employability represents both a legal challenge and a structural social concern. Employability encompasses more than formal labor force participation; it includes access to recruitment processes, opportunities for career advancement, job security, and substantive involvement in organizational decision-making. Persistent structural barriers, including the sexual division of labor, caregiving responsibilities, and gendered expectations, continue to constrain women's employment trajectories, particularly in technology-driven sectors. Consequently, employability should be analyzed through the lens of substantive equality and labor rights, rather than being confined to individual qualifications or market adaptability.

The adoption of AI-based systems in employment decision-making further intensifies these dynamics. Although algorithmic tools are often perceived as objective and neutral, they are constructed upon datasets and models shaped by historically biased social structures. As a result, gender-based algorithmic discrimination may emerge in automated hiring, ranking, monitoring, and promotion systems, perpetuating exclusion under the guise of technical rationality. These developments challenge core legal principles, including equality, non-discrimination, transparency, and accountability, and reveal substantial shortcomings in existing regulatory frameworks governing the intersection of work and technology.

In this context, the concept of just transition offers a vital normative framework for addressing the gendered impacts of technological transformation. Originally developed in response to environmental and economic restructuring, just transition has expanded into a comprehensive legal and policy paradigm aimed at aligning technological innovation with social justice, decent work, and human rights. Within AI-driven labor markets, a gender-responsive just transition requires regulatory strategies that integrate equality considerations into technological governance, corporate practices, and public policy. This article argues that only through such an integrated approach can the intensification of gender inequalities be prevented and digital transformation be aligned with democratic standards and substantive gender equality in the workplace.

1. Female employability and structural gender inequalities in the world of work

The history of societies has long been structured by narratives permeated by an "absent presence" of the feminine. According to Caroline Perez (2022, p. 68), this manifests in the systematic erasure of women from the data, statistics, and accounts that organize social life.

Under the predominance of patriarchy, a hierarchical vision of male supremacy was consolidated, expressed through a systematic distortion of reality that "sees men as the human default in the structure of society" (Perez, 2022, p. 135). As a result, historically male-centered narratives are elevated to the status of universal parameters and presented as impartial and unbiased, when in fact they merely reflect specific positions, typically formed by structures of privilege.

It is through these dominant discourses that a partial vision of the world is legitimized as general and homogeneous, while social and cultural forms that do not conform to this model are silenced, marginalized, or disqualified. Consequently, women's experiences are relegated to the status of exception, reduced to a mere social niche (Perez, 2022, p. 372).

According to Joan Scott (1995, p. 92), the binary opposition – male versus female -and the social construction of gender relations have been intrinsically associated with the representation of power. Therefore, questioning or altering any of their structural components threatens the entire system. As a result, a silent dynamic of privilege preservation persists, sustained over time by gaps in data related to what is understood as feminine. As Perez (2022, position 75) explains, this phenomenon does not generally arise from deliberate intent or bad faith, but rather from a historical pattern of thought that naturalizes men as the representation of the human being, rendering women invisible in analyses and records.

The historical erasure of women is largely attributable to unequal access to the mechanisms that shape social life, particularly in the world of work. In this domain, gender inequality manifests in multiple ways: in the lower proportion of women in formal employment; in barriers to hiring pregnant women; in the lack of institutional support for breastfeeding workers; in the reinforcement of occupational niches traditionally considered masculine, such as STEM fields – commonly justified by narratives of meritocracy or presumed natural aptitude; in reduced opportunities for promotion; and in persistent pay gaps. According to the International Labor Organization – ILO (2026):

> In 2025, women accounted for only two-fifths of global employment, showing considerable barriers to employment. Globally in 2026, women are projected to face a 0.2 percentage-point higher unemployment rate and a 4.3 percentage-point higher jobs gap rate relative to men (ILO, 2026, p. 9).

Because women are not culturally associated with objectivity, leadership, or proactivity – but rather with reproduction, caregiving, and fragility, traits classically linked to performances of femininity – their competence is frequently questioned, delegitimized, or subjected to more rigorous evaluation standards. This occurs within a framework that presumes women to be inherently less capable. This structural phenomenon is widely recognized as the sexual division of labor.

The sexual division of labor refers to the polarized allocation of human activities, in which men are assigned central roles in certain tasks while women are assigned to others. In abstract terms, such a division would not necessarily be problematic; however, in practice, it operates through the hierarchical valuation, assigning greater social and economic value to activities associated with men, while those associated with women are systematically undervalued. In this sense, this division produces inequality and, historically, has contributed to the marginalization and subordination of women (Rocha and Andrade, 2024, p. 351).

In this regard, the words of Maria Rosa Lombardi and Cristina Bruschini (2020, p. 70) are particularly illustrative:

> The feminization of domestic work is not surprising. In our society, household responsibilities are considered women's responsibility, regardless of their social status, family position, or whether they engage in paid work outside the home. When these tasks are performed by housewives within the family setting, they are not recognized as work and are recorded in official statistics as economic inactivity. [...] Productive and reproductive labor constitute distinct spheres, yet both are equally essential to the maintenance of families. The interconnection between these spheres reveals that the workday encompasses not only paid labor but also unpaid labor directed toward social reproduction, particularly care-related activities.[4]

Therefore, for women situated within the sphere of reproductive labor to attain positions of power, leadership, or social prestige, they are required to demonstrate extraordinary talent – far exceeding the standards typically required of men. Given the perceived exceptional nature of their performance, their presence in such roles demands social justification grounded in presumed intellectual exceptionalism (Storage et al., 2015).

The ILO report (2026) further confirms the persistence of inequality in the labor market:

> While the global unemployment rate is projected to remain at the historically low level of 4.9 per cent in 2026, around 284 million workers still live in extreme poverty – on less than US$3 a day – and more than 2 billion workers remain in informal employment. Worryingly, the number of working poor and informal workers is rising in low-income countries, highlighting a lack of progress where it is needed most. Gender gaps also remain widespread throughout the world of work, with limited advances in only a few areas, such as the reduction in contributing family work (ILO, 2026).

Gender gaps in the labor market are also evident in highly visible and prestigious contexts, such as the political sphere, where women remain underrepresented. This underrepresentation reveals one of the most severe dimensions of the gender data gap: even when women attain positions of prestige and perform decisive functions in traditionally male-dominated fields, their contributions persist in being systematically erased, undervalued, or excluded from historical records. A remarkable example is presented in Jennifer Light's *article "When Computers Were Women"* (1999).

This publication features the work of six women involved in the development of ENIAC, the first electronic ballistic computer in the United States, launched in 1946, and demonstrates how women's participation in science and technology was directed by gender norms. Initially, their inclusion was enabled because of factors such as limited budgets, the availability of educated women, the shortage of men, the presence of female intermediaries (such as the wives of scientists), and relatively progressive

[4] This quotation was freely translated into English by the authors for clarity and accessibility to an international academic audience. The original version was published in Portuguese.

employers – even within environments generally resistant to women's entry into traditionally male-dominated fields (Light, 1999, p. 459).

Although these women performed essential functions as "ballistic computers" and "operators" (programmers) – roles requiring high-level mathematical knowledge and technical skill – their work was classified as administrative, thereby undervaluing their contributions. This gendered classification of occupations had precedents dating back to the late nineteenth century, when feminized roles emerged throughout various scientific fields, with women working alongside men but receiving less recognition (Light, 1999, p. 458).

This rewriting of technological development not just erased women's protagonism but also consolidated a depreciative perception of their capabilities in this field. As a result, incomplete historical accounts reinforced the belief that programming and coding are, and have always been, inherently male activities (Light, 1999, pp. 482–483).

Based on the mistaken assumption of women's supposed incapacity to perform in technological fields, a persistent fallacy emerged – one that continues to shape contemporary society. This fallacy contributed to a stigmatized division of labor, in which certain activities came to be regarded as more suitable for men, while others were culturally assigned to women.

As bell hooks (2019, p. 2079) argues, it was through these structural conditionings that women came to be exploited both economically and psychologically in the workplace. Formed by unequal narratives along with institutional practices, women were led to internalize the devaluation of their own labor. On the one hand, sexist educational structures contributed to the systematic underestimation of their labor capacity; on the other, consumerism conditioned women to perceive the value of work primarily in terms of material provision, rather than its wider social contribution, its creative potential, or its capacity to generate fulfillment for themselves and others.

These structural impositions continue to persist, promoting the reproduction of gender-based discrimination in contemporary society. With the rise of surveillance capitalism in the twenty-first century, these dynamics have reached an unprecedented scale. According to Zuboff (2021, p. 14), the transformation of industrial capitalism in the nineteenth and twentieth centuries already represented a serious threat to human nature, due to the unprecedented concentration of wealth, knowledge, and power capable of imposing a new collective order based on instrumental power, therewith compromising individual sovereignty.

In this context, the world of work is undergoing major shifts as artificial intelligence (AI) systems become increasingly embedded in workplace organization and domestic arrangements. Although women's participation in the labor force expanded globally throughout the twentieth century, considerable structural barriers persist, and gender equality remains far from fully realized, both within and beyond the paid workforce.

2. The patriarchal reproduction of inequalities in labor relations and their effects on the algorithmic invisibilization of gender

> "The representation of the world, like the world itself, is the work of men; they describe it from their own point of view, which they confuse with absolute truth."
>
> (Beauvoir, 2011, p. 183)

Building upon the structural analysis of gender inequality presented in the previous section, this chapter examines how artificial intelligence systems may reproduce and increase these asymmetries through algorithmic decision-making processes.

In the digital age, with the expansion of Big Data, data extraction has transformed algorithms into fundamental instruments for measuring, categorizing, selecting, and reorganizing the processes through which individuals communicate in contemporary society, directly shaping social relations and behavioral patterns. For Cathy O'Neil (2021), an algorithm means:

> [...] nothing more than the abstract representation of some process, be it a baseball game, the logistics chain of an oil company, the actions of a foreign government, or the audience of a movie theater. Whether it's running inside a computer or in our heads, the model takes what we know and uses it to predict responses in a variety of situations. We all carry thousands of models in our heads. They tell us what to expect and guide our decisions (O'Neil, 2021, p. 19).

In a society structured by symbolic arrangements of power and oppression and defined by well-entrenched discriminatory practices, gender inequalities persist and are reproduced within algorithmic constructions and artificial intelligence models. Through incorporating gender biases, these systems sustain existing structures of oppression, which also manifest through intersectional markers – even when reflected implicitly. As Crestane and Leal (2024, p. 19) explain: "In general terms, algorithmic discrimination is understood as the automated denial of an individual's access to a particular good, right, or service based on an erroneous or biased algorithmic inference".[5]

The operation of algorithmic models may be defined as a process structured around datasets that form extensive informational bases. When a new input is introduced and associated with a specific algorithmic command (prompt), the system generates a corresponding output. This process indicates the capacity of algorithmic systems to observe patterns, perform classifications, and generate predictive responses based on previously structured data.

However, when such systems are integrated with artificial intelligence, the risks are significantly amplified due to their improved potential for harm. Unlike traditional computational models, AI systems are distinguished by four specific characteristics: imprecision, dynamism, associative capacity, and learning capability. These properties render system behavior neither entirely predictable nor fixed, but rather dependent on data inputs, interactions, and contextual variables.

[5] This quotation was freely translated into English by the authors for clarity and accessibility to an international academic audience. The original version was published in Portuguese.

In this regard, Morato and Nunes (2025, p. 61) clarify that although algorithms do not possess subjective intentionality, they operate through calculations, predictions, and behavioral reorganization. As a result, artificial intelligence should not be understood merely as an extension of human action, but as a non-human agent that operates performatively, guided by data and frequently characterized by operational opacity.

It is precisely this operational complexity that gives rise to specific situations in which algorithmic failures may emerge, often difficult to anticipate or detect in advance. According to Morato and Nunes (2025, p. 73), these failures may be classified into four categories: (1) problematic input data; (2) operational limitations; (3) contextual inadequacy; and (4) flawed design or training. Each of these categories will be examined below.

The first category, related to failures arising from problematic input data, occurs when incomplete, inaccurate, or misinterpreted information is incorporated into the dataset, resulting in structural inconsistencies and distorted outputs. In such cases, sampling bias compromises the model's generalization capacity, causing inaccurate associations and unreliable inferences.

This phenomenon is illustrated by a study conducted by researchers from the AI startup Hugging Face and the University of Leipzig, which examined bias reproduction in three widely used AI image generation models: DALL-E 2 and the two most recent versions of Stable Diffusion. The analysis uncovered a systematic tendency of these models to reproduce racial and gender stereotypes, particularly by representing white men when prompted to illustrate positions of authority. In the case of DALL-E 2, this tendency was even more pronounced: in 97 percent of requests involving terms such as "CEO" or "director," the generated images depicted white men (Heikkilä, 2023).

The study further revealed that, when analyzing another AI tool that allows users to observe how the application of different adjectives influences generated images, the results frequently reflected gender stereotypes. For example, adjectives such as "compassionate," "emotional," or "sensitive," when associated with professional roles, tended to generate images of women, whereas terms such as "stubborn," "intellectual," or "irrational" predominantly produced images of men (Heikkilä, 2023).

Failures arising from operational limitations, in turn, may be understood as resulting from a mismatch between the algorithmic model's technical infrastructure and the context in which it is applied. Even when both the data and the model are theoretically adequate, insufficient computing resources, instability in the execution environment, or incompatibility between the system and its application domain may compromise performance, producing errors, distortions, or unstable results.

This issue is illustrated by a report published by*The Intercept Brasil*, which presented cases demonstrating unexplained disparities in recruitment platforms that use artificial intelligence algorithms. One example involved a software developer whose application was rejected by the platform Gupy, while her sister – who lacked appropriate experience and provided lower-quality responses – advanced in the selection process. Furthermore, according to human resources specialists interviewed in the report, such platforms tend to reproduce structural biases in the labor market, disadvantaging women in technology fields, assigning lower scores to older candidates,

and privileging graduates from institutions with higher ratings from Brazil's Ministry of Education (Neves, 2022).

The report also identified that, in the case of Gupy, the algorithm assesses candidates based on multiple criteria, including professional experience, academic qualifications, geographic location, behavioral profile, organizational culture alignment, and personal interests. Additionally, former employees reported that factors such as age, time since graduation, and residential proximity to the company strongly influence candidate scoring, favoring younger applicants, recent graduates, and those living closer to company headquarters. Similarly, Rocketmat, another company operating in this sector, uses a methodology analogous to credit scoring systems, assigning each candidate a numerical score that summarizes their profile and determines their ranking for available positions (Neves, 2022).

Contextual inadequacy represents another category of algorithmic failure. This occurs when the model is unable to adequately capture, interpret, or respond to the specific social, institutional, or circumstantial context in which it is deployed. In such cases, systems are used outside their original design parameters, widening the gap between algorithmic-based abstractions and the intricate realities they seek to model. This misalignment may involve linguistic, cultural, or geographic differences, as well as shifts in user anticipations and behavioral norms, resulting in inaccurate, inadequate, or irrelevant outputs.

An illustrative example is an investigation by AlgorithmWatch, which found that Google Translate exhibits gender bias when translating between languages, particularly those with grammatical gender, such as German, French, Spanish, and Portuguese. For instance, the phrase "vier Historikerinnen und Historiker" ("four female historians and four male historians") was translated into Spanish as "cuatro historiadores" ("four historians"), with similar distortions observed in Italian, French, and Polish. Furthermore, Google Translate altered the gender of certain words in stereotypical ways: "Die Präsidentin" ("the female president") was translated into Italian as "il presidente," although the correct feminine form is "la presidente," while "Der Krankenpfleger" ("male nurse," in German) was translated into French as "l'infirmière" ("female nurse") (Kayser-Bril, 2020).

The final category of algorithmic failure concerns deficiencies in model design or training. These failures may arise from methodological errors, flawed design choices, or insufficient or improperly calibrated training procedures. As a result, systems may produce highly inaccurate inferences, improperly generalize patterns, and generate outputs that do not reliably reflect the realities they are intended to represent.

Morato and Nunes (2025, p. 79) further explain that design failures may lead to inefficiency or poor system performance, while training failures may result in overfitting or underfitting. These aberrations have been observed in Google's search engine. For example, searches for images of "mulher negra dando aula" ("Black woman teaching") predominantly produced pornographic content, whereas searches for "mulher dando aula" ("woman teaching") or "mulher branca dando aula" ("white woman teaching") yielded entirely different results, displaying images of teachers – predominantly white women – in classroom environments, interacting with students or writing on blackboards (Oliveira, 2019).

Given these examples, it becomes paramount to address historical and cultural asymmetries as part of an integrative solution that reconciles technological development with the protection of fundamental rights, guaranteeing that existing rights are preserved and preventing inequalities or unjust practices from intensifying violations of human dignity. Nevertheless, despite the risks associated with artificial intelligence, global development efforts remain largely driven by economic incentives focused on technological modernization and sectoral competitiveness.

In this context, the adoption of corporatist governance models tends to reinforce historical dependencies and raise barriers to entry for new actors in the AI market (Filgueiras and Junquilho, 2023). Moreover, another recurring issue derives from the assumption that "[...] "It is therefore assumed that Latin American countries are characterized by similar structural problems and that a joint approach, grounded in a dialogical framework, could constitute a regional solution." (Crestane and Leal, 2024, p. 20).[6]

However, this assumption gives rise to two fundamental misconceptions. The first consists of adopting legal transplants from Global North countries without adapting them to the specific realities of the Global South, thereby intensifying existing structural inequalities and exacerbating social, economic, and human rights risks. The second lies in the mistaken belief that formal legal equality alone is sufficient to achieve substantive equality. Without structural transformation, formal legal frameworks may inadvertently reinforce exclusion and perpetuate the historical marginalization of vulnerable groups.

In Brazil, the absence of comprehensive AI regulation, combined with a lack of national coordination, has contributed to the recurrence of discriminatory outcomes resulting from violations and threats to fundamental and human rights arising from the deployment and operation of these systems.

Accordingly, there is a pressing need to restructure and adapt institutional frameworks in light of emerging legislative developments and public policy requirements specific to the digital and technological era. Such efforts must remain centered on the human person, incorporating recognition of local and individual-specificities that shape national realities, in order to ensure the effective realization of substantive equality.

3. Just transition as a normative political instrument for the promotion of gender equality in the fourth industrial revolution

In light of the structural and technological dynamics examined in the previous sections, this chapter introduces just transition as a normative framework for addressing the gendered impacts of technological transformation.

As outlined in the previous section, the concept of just transition remains in the process of consolidation, being employed across distinct disciplinary fields with varying emphases. In its original formulation, linked to the international labor movement, just transition refers to a set of compensatory measures aimed at protecting

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workers affected by processes of productive restructuring, particularly those resulting from economic decarbonization and environmental sustainability policies. This predominantly socioeconomic interpretation emphasizes employment protection policies, professional retraining, and measures to mitigate income loss.

Contemporary scholarship, however, has expanded this scope. Within the fields of environmental justice and political economy, just transition is increasingly understood as a structural process of transformation, oriented not only toward changes in the energy matrix but toward the broader reorganization of the relationships among economy, technology, labor, and society. From this perspective, scholars such as McCauley, Field, and Todd (2024) argue that the justice of transition must be assessed through three complementary dimensions: distributive, procedural, and restorative.

It is within this expanded framework that the concept is incorporated into the Elena Piscopia OEI Chair Report, which proposes understanding just transition as a transversal fundamental right, endowed with its own normative density and directly linked to the protection of human rights in contexts of accelerated structural change (Machado et al., 2025). This interpretation is consistent with the theoretical framework adopted in this article by recognizing that technological and productive transformations – such as artificial intelligence and the energy transition – affect the very content and exercise of fundamental rights, thereby requiring legal responses that transcend isolated sectoral policies.

Accordingly, throughout this section, just transition will be understood not merely as a public policy framework but as a guiding normative instrument capable of articulating gender equality, decent work, technological governance, and democracy.

3.1. Artificial intelligence and work: conceptual disputes and gendered impacts

The term artificial intelligence also encompasses multiple definitions. In the technical field, it refers to computational systems capable of performing tasks that traditionally require human cognition, such as classification, prediction, and decision-making. In the legal and socioeconomic context, however, AI must be understood as the operational expression of a sociotechnical system, whose functioning results from the interaction among algorithms, datasets, institutional structures, and human decision-making.

This distinction is central to understanding its impacts on labor. Recent scholarship has moved away from the notion of automatic job replacement and instead emphasizes the reorganization of tasks that constitute occupations, producing uneven effects across sectors, territories, and social groups (Schymura, 2026). In this context, gender emerges as a critical analytical variable.

Several studies indicate that women are disproportionately concentrated in occupations with higher exposure to algorithmic automation, while simultaneously remaining underrepresented in strategic sectors of the digital economy. Minharro, Pascini, and Ferreira (2024) demonstrate that this asymmetry results not merely from individual choices but from structural factors, including educational barriers, the sexual division of labor, and the absence of technological inclusion policies.

Furthermore, legal scholarship highlights that AI systems applied to human resource management – such as recruitment, performance evaluation, and career progression – tend to reproduce and intensify historical biases, particularly when operating on datasets shaped by gender inequality (Besteti & Von Hohendorff, 2022). In this regard, the uncritical adoption of such technologies within corporate environments may directly undermine the principle of substantive equality. It is precisely at this juncture that just transition emerges as an indispensable normative criterion, requiring that the incorporation of AI be accompanied by governance mechanisms, transparency safeguards, professional retraining initiatives, and meaningful social participation, with particular attention to women.

2.2. Latin America and Brazil: just transition, structural inequality, and the digital divide

In the Latin American context, the effects of artificial intelligence on labor are shaped by historical inequalities that predate the digital revolution. High levels of informality, lower average educational attainment, and limited technological infrastructure create conditions in which the productivity gains associated with AI are not equitably distributed.

A joint report by the International Labour Organization and the World Bank indicates that a significant proportion of occupations in the region, although theoretically exposed to AI, are unable to benefit from these technologies due to digital exclusion—a phenomenon that disproportionately affects women and low-income workers (Gmyrek, Winkler & Garganta, 2024).

In Brazil, these challenges are compounded by persistent gender inequality in the labor market, reflected in wage disparities, occupational segregation, and the underrepresentation of women in decision-making positions. The introduction of AI, in the absence of a framework guided by just transition principles, tends to deepen these asymmetries, displacing women into more precarious forms of employment or excluding them from sectors undergoing accelerated technological transformation (Meireles, 2024).

The Elena Piscopia OEI Chair Report argues that, in Global South countries, a just transition must necessarily incorporate a gender perspective, otherwise risking the consolidation of new forms of technological dependency and inequality. In the Brazilian case, this requires recognizing that both the digital and energy transitions must be accompanied by deliberate policies to promote women's inclusion in strategic sectors of the green and digital economy (Machado et al., 2025).

2.3. Just transition, democracy, and human rights: an integrative perspective

Techno-academic scholarship converges on the conclusion that the absence of policies guided by just transition principles represents not only an economic risk but also a threat to democracy and human rights. The concentration of the benefits of technological and energy transformations among restricted groups tends to exacerbate structural inequalities, thereby undermining democratic legitimacy and social cohesion (Velicu & Barca, 2020).

With regard to women, inaction in the face of the consolidation of artificial intelligence and the energy transition may result in the crystallization of a deeply unequal labor market, in which automated, opaque, and socially unaccountable decision-making processes come to determine professional opportunities and career trajectories. Such a scenario compromises fundamental rights, including substantive equality, decent work, and full participation in economic and political life.

In light of these considerations, the right to just transition must be understood as an emerging human right, capable of guiding the regulation of artificial intelligence, corporate conduct, and public policy development. According to Machado et al. (2025), the principle of ensuring that no one is left behind amid structural transformation is not merely a political choice but a legal imperative consistent with contemporary democratic values.

Conclusion

The analysis shows that, at present, there is no definitive consensus regarding the full extent to which AI-driven automation will reshape women's employment. Nevertheless, the expanding capacity of artificial intelligence to perform not only routine but also complex and non-routine tasks illustrates the depth and structural nature of the ongoing transformation in the world of work, with differentiated and potentially uneven consequences across gender lines.

From an employability perspective, the expansion of AI-mediated labor markets requires a reconceptualization of access to work that goes beyond formal labor force participation. Women's employability in contexts of technological transition must be understood as a multidimensional condition, encompassing not only access to skills development but also equitable participation in recruitment processes, career advancement opportunities, and decision-making spaces within organizational structures. Absent gender-responsive transition policies, technological transformation risks reinforcing occupational segregation and aggravating existing structural barriers to women's full, dignified, and sustainable participation in the labor market.

In this context, it becomes imperative for governments, public institutions, and private organizations to adopt proactive, coordinated strategies to ensure women's access to digital literacy, advanced AI-related competencies, and non-automatable skills—particularly those associated with interpersonal, relational, and socio-emotional capacities. These competencies are likely to constitute central pillars of future labor markets, and their equitable distribution represents a necessary condition for preventing the reproduction of structural gender inequalities within AI-mediated employment systems.

Accordingly, embedding gender equality at the core of just transition frameworks is essential to ensuring that technological transformation serves as a mechanism for advancing substantive equality rather than reinforcing historical patterns of exclusion. A gender-responsive just transition requires the articulation of legal, institutional, and corporate governance mechanisms designed to mitigate algorithmic bias, promote inclusive workforce development, and ensure that emerging technological systems operate in accordance with principles of transparency, accountability, and non-discrimination.

In this sense, just transition must be understood not merely as a policy objective, but as a normative and legal commitment to aligning technological innovation with fundamental rights, democratic values, and social justice. By integrating gender equality into the governance of artificial intelligence and the restructuring of labor markets, just transition emerges as an essential framework for ensuring that the Fourth Industrial Revolution does not reproduce historical inequalities, but instead contributes to the construction of more inclusive, equitable, and rights-based labor systems.

Ultimately, ensuring that the Fourth Industrial Revolution unfolds in a manner consistent with gender equality, democratic governance, and human dignity requires recognizing just transition as a legal and normative obligation. Without such a framework, artificial intelligence risks reinforcing historical patterns of exclusion rather than advancing substantive equality.

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Neurotechnologies and mental health in childhood: a reading from the brazilian context

GABRIELLE BEZERRA SALES SARLET[1]

VIVIANE CEOLIN DALLASTA DEL GROSSI[2]

Contents: Introductory elements; 1. Notes on mental health in Brazil; 2. Neurotechnologies; 3. Children's health in the age of artificial intelligence; 3.1. Mapping the brazilian landscape of child protection; Final considerations; References.

Introductory elements

The current scenario of technocultural revolution, marked by significant complexity, implies attention and, consequently, qualified investigation (Coleman, 2019), in order to obtain a clearer perspective on constitutional and legal frameworks, appropriate governance policies, and regulatory approaches and arrangements compatible with the protection of human beings, particularly the hyper-vulnerable.

Faced with the contemporary panorama, characterized by the pervasive dissemination of Artificial Intelligence (AI) tools — capable of radically intervening in social and cognitive processes and in areas traditionally restricted to human care — it

[1] Lawyer, graduated and holds a master's degree in Law from the Federal University of Ceará (UFC). Specialist in neuroscience and behavioral sciences from the Pontifical Catholic University of Rio Grande do Sul (PUCRS). PhD in Law from the University of Augsburg (UNIA) in Germany and postdoctoral fellow at the University of Hamburg and the Pontifical Catholic University of Rio Grande do Sul (PUCRS). CNPq Productivity Researcher. Coordinator of the Law and Artificial Intelligence Research Group (GDIA/INSPER). Associate Professor of the Law Course at the Institute of Education and Research (INSPER). Full member of the National Council for Data Protection and Privacy (CNPD) and the National Technical Chamber of Ethics and Investigation of the National Transplant System (SUS). President of the Rio Grande do Sul regional branch of the Brazilian Society of Bioethics (SBB). Member of the Intersectoral Commission on Science, Technology and Pharmaceutical Assistance (CICTAF) of the National Health Council (CNS). E-mail:gabriellebezerrasales@gmail.com

[2] PhD in Human Rights from the University of São Paulo (USP). Master of Human Rights from USP. Master in Criminology and Penal Execution from Pompeu Fabra University (Interinstitutional degree from the University of Girona and the Autonomous University of Barcelona – Barcelona, Spain, 2014). Postgraduate degree in Public Law, with an emphasis on International Human Rights Law. Member of the Ethics, Human Rights and Artificial Intelligence Research Group (EDHIA/ENADPU/DPU). She was a UNESCO researcher for the implementation of the Recommendation on Ethics and AI in Brazil, 2025. Federal Public Defender since 2009.ORCID: https://orcid.org/0000-0003-3104-0091. E-mail: viviane.dallasta@dpu.def.br.

becomes imperative to analyze their effects on childhood. From a critical perspective, this study proposes an investigation into the impacts of AI tools and, specifically, neurotechnologies on the mental health of children. To this end, the hypothetical-deductive method is used, based on qualitative research and exploratory-bibliographic methodologies, highlighting the protective system in Brazil and its new layers of child protection.

Under the 1988 Federal Constitution, it is necessary to densify an analysis that goes beyond a perfunctory exegesis of human and fundamental rights. It is urgent to scrutinize the duties constitutionally attributed to the Family-Society-State triad regarding the comprehensive protection of children and their absolute priority, especially in the face of the indistinction between the real and digital environments. Under this scrutiny, the aim is to highlight the risks inherent in the "techno-enthusiast" dynamic in the unreflective use of AI and neurotechnologies.

After mapping these risks and benefits, it becomes opportune to confront this reality with the Brazilian normative framework. The central objective is the construction of a roadmap that identifies effective instruments for the protection of human and fundamental rights, in light of the innovations introduced by Law 15.211/2025 — the so-called "Digital Child and Adolescent Statute" (Digital ECA).

In line with this purpose, the following premises are used: a) Brazil is not in a state of absolute regulatory vacuum regarding the rights of children and adolescents in the digital environment, and it remains to foster an agenda aimed at debating and implementing the issues related to the absolute priority and best interest, and consequently, the full protection of children in an environment of complex fusion between the real and the digital; b) the international environment, as has occurred in Brazil, has become sensitive to the risks, initiating a significant movement in favor of the debate regarding the harmful uses of AI and neurotechnologies for the mental health of children, forging protocols, declarations and guiding recommendations that demonstrate the multidimensionality of a protective system truly adequate to the current moment; c) Brazilian legislation, including that which is in vacatio legis, still lacks a regulatory process, and should be the result of broad popular participation so that it culminates in public policies adequate to the duties imposed on the various actors in the face of the aggressive and techno-authoritarian geopolitical context; d) There is an undeniable wave of warnings from respected experts in various fields regarding so-called negative externalities and the real risks of damaging impacts on generational losses in terms of intelligence, memory, sociability, and attention, with the potential for lasting brain transformations (Desmurget, 2021) in children subjected to a techno-enthusiastic, unregulated, or insufficiently regulated environment; e) In all areas, including the field of applied social sciences, several serious studies refute the argument of inevitabilism[3] (Zuboff, 2020); f) There is a multiplicity, not a single, pattern of childhood, especially in unequal countries like Brazil; g) There is an intrinsic difficulty in addressing mental health, especially that of children, due to persistent taboos.

Regarding risks, it is worth recalling the taxonomy of the four C's, which—comprising Content, Contact, Conduct, and Contract—establishes the fundamental

[3] The author refers to the logic of *Big Techs* as "The puppet master, not the puppet," because the fact that surveillance capitalism is a logic in action and not a technology per se is a vital point, since surveillance capitalists want us to think that such practices are inevitable expressions of the technologies they employ (pp. 26-7).

pillars for the protection of children in the digital ecosystem, aligning with the best interest and absolute priority guidelines of the Brazilian scenario. In the Content area, the focus is on combating access to dangerous materials and sexual exploitation, while the Contact pillar aims to mitigate risky interactions with strangers through parental control tools. Complementarily, the Conduct axis is dedicated to education for safe behavior, preventing, for example, cyberbullying and the development of technological dependencies, thus mitigating the risks of brain transformations and losses of sociability already detected by experts.

Under the ECA Digital (Law 15.211/2025), the Contract pillar gains special relevance by prohibiting behavioral profiling and the commercial use of minors' data, combating the logics of "surveillance capitalism" and the "attention industry." This contractual dimension requires rigorous oversight and a redefinition of the informed consent of those responsible, ensuring that the management of personal data does not compromise the autonomy or psychic integrity of children. In this way, the integration of these four pillars seeks to align all efforts in an effective and efficient system.

This manuscript is the result of a critical analysis of the socio-technical implications inherent in the advancement of neurotechnologies, supporting the premise that any regulatory agenda should foster debates based on the defense of civilizational paradigms. It is essential to assume the non-negotiable maintenance of human values and the safeguarding of the mental and emotional health and well-being of children and adolescents, both in the physical sphere and in the digital environment. Thus, while envisioning the potential benefits of AI technologies, society cannot ignore the risk of reversing the human-centered paradigm, which could lead to dystopian conditions where the artifice ends up turning against its own creator.

Due to the focus of this publication, the limited number of pages, and the epistemological cuts agreed upon for the preparation of the manuscript, it is warned that some topics affecting the health of children in countries of the southern hemisphere, that is, peripheral countries, such as Brazil, will be addressed, but not explored in depth, e.g., digital colonialism, digital sovereignty, technocracy, technological dependence, interoperability, digital infrastructures, digital divide, concentration of power, and due informational process.[4]

Finally, despite what could already be extracted from the current version of PL 2338, due to the state of transience and ephemerality that has characterized the legislative process around the topic of artificial intelligence regulation in Brazil (Gomes and Rodrigues, 2026), it was decided not to address any of the bills under consid-

[4] In this topic, for a better understanding, cf, v.g., Chen, L., Day, T. W., Tang W., John, N. W. Recent Developments and Future Challenges in Medical Mixed Reality. In IEEE International Symposium on Mixed and Augmented Reality (ISMAR), pp. 123-135; SOUZA, Joyce Souza; MALDONADO, Fabio. Saúde digital e o aprofundamento da dependência tecnológica. Disponível em: https://diplomatique.org.br/saude-digital-dependencia-tecnologica/. Acesso em: 21.03.2025; Sales Sarlet, G. B. (2025). O DIREITO HUMANO E FUNDAMENTAL À SAÚDE E OS IMPACTOS DO OPEN HEALTH NO CENÁRIO BRASILEIRO. *Revista Direitos Fundamentais & Democracia*, *30*(2), 148–180. https://doi.org/10.25192/ISSN.1982-0496.RDFD.V.30.II.2853 Acesso em: 03.jan.2026; Sarlet, G. B. S., & Mendes, B. L. (2020). NOVAS TECNOLOGIAS, DIVISÃO DIGITAL E O DIREITO À SAÚDE EM TEMPOS DE COVID-19: PERSPECTIVAS DE GESTÃO E DE GOVERNANÇA NO BRASIL. *Direito Público*, *17*(94). Recuperado de https://www.portaldeperiodicos.idp.edu.br/direitopublico/article/view/4473 Acesso em: 03.jan.2026; CRAWFORD, Kate; SCHULTZ, Jason. Big data and due process: Toward a framework to redress predictive privacy harms. *BCL Rev*., v. 55, p. 93, 2014. Disponível em: https://lawdigitalcommons.bc.edu/bclr/vol55/iss1/4.

eration in parliament in depth, reserving this for another opportunity in which more mature elements are identified in a legal framework for AI. As a final reminder, it should be noted that this is not intended to be an exhaustive discussion of the topic, but rather to clarify the panorama and encourage debate.

1. Notes on mental health in Brazil

The right to mental health is an essential aspect of the right to health guaranteed by the Federal Constitution, in its article 6, as a fundamental social right, which includes mental health within this framework, including article 196 of the Constitution which states that: "health is a right of all and a duty of the State", through universal and equal access to health actions for promotion, protection, prevention and recovery (Ministry of Health, Brazil, 2026).

Since the constitutionalization of this right in 1988, the need for specific attention to the integral health of the person has led to mental health care as a logical consequence of this right, as a duty and responsibility of the State to offer dignified conditions from this perspective of care for the entire population. According to the World Health Organization (WHO), mental health can be considered a state of well-being experienced by the individual, which enables the development of their personal skills to face and manage life's challenges and contribute positively to the community, which goes beyond merely individual psyche aspects, being determined by environmental, social and economic aspects.

The WHO's founding document, in addition to what is established above in its preamble, emphasizes in relation to mental health, in its article 2, letter "m", that activities in the area of mental health should be promoted, especially those that affect the harmony of human relations (WHO, 1946).

This consideration has gained prominence in recent years, based on the awareness of all the factors involved in guaranteeing and promoting the right to mental health in Brazil, such as the intersection of numerous related factors.

April 2026 marks the twenty-fifth anniversary of Law No. 10,216, legislation that instituted the Psychiatric Reform and reoriented the model of mental health care in Brazil by recognizing the rights of people in need of special care due to mental health and the use of alcohol and other drugs. This law was the decisive institutional impetus for replacing the asylum model with a network of open, territorial, and community-based services, consolidating itself as a normative icon that promotes and expands the spectrum of freedom while ensuring the status of subject of rights for all, indiscriminately.

By affirming the dignity of these people, the law guaranteed not only the right to care in freedom, but also reaffirmed access to housing, work, belonging, and active participation in public and community life. Beyond deinstitutionalization, Law 10.216 legitimized modes of expression of subjectivity and affections, establishing the basis for each citizen to have the freedom to live their own future project. In this way, the legislation brought about a profound transformation by simultaneously ensuring liberation from the asylum and the fundamental right to a common and integrated life in the community.

In Brazil, the Pan American Health Organization's Cooperation Strategy 2022-2027 (PAHO/WHO) treats mental health care in the country as a strategic priority given the worsening situation after the Covid-19 pandemic, including actions aimed at children and adolescents. This situation is corroborated by recent research conducted by the Brazilian Psychiatric Association (ABP) with parents of children and adolescents in Brazil, which identified that 70% of families have already sought help to care for their children's mental health (ABP Brazil, 2025).

This study took place within the context of a more comprehensive survey conducted with different age groups in September 2025 by the ABP, aiming to understand the main challenges faced by the Brazilian adult population in relation to mental illnesses. One piece of data that drew attention is that 50.9% of people have already sought care from psychiatrists or psychologists at least once and are being monitored by specialized professionals. Furthermore, 25.7% of participants reported having suicidal thoughts in the past six months, and 25.2% stated that they do not feel well currently (APB, 2025).

This warning has led to a deeper official analysis of this situation in the national context, and in early 2026, the federal government launched a groundbreaking survey to produce strategic information for strengthening public policies, with the implementation of the National Mental Health Survey (PNSM-Brasil). It is the first large population-based study specifically aimed at understanding the mental health situation of the adult population throughout the national territory (Ministry of Health, Brazil, 2026).

Regarding attention to the mental health of children and adolescents, considering that early childhood, childhood, and adolescence are stages of hyper-vulnerability and, consequently, that windows of opportunity emerge for the mental health of this developing biopsychosocial population (SECOM/PR, 2025), Federal Law No. 15.100/2025 is already in effect in Brazil. This law stipulates that the psychological suffering and mental health of students, in relation to experiences involving the digital environment, should be the target of preventive and protective strategies, especially those managed in school environments. Thus, school systems and schools should offer periodic training on the subject and provide listening and support spaces to receive students who are experiencing psychological and mental distress, mainly due to the immoderate use of screens and nomofobia (Article 4, §2, of Law 15.100/2025).

Regarding the digital ecosystem, a consensus has been consolidated in the scientific community that certain mechanisms or "hidden patterns"[5] of applications can be harmful to children and adolescents, given the potential to induce excessive or harmful uses. Such mechanisms, driven by Artificial Intelligence tools, tend to worsen in the absence of safeguards established with the necessary commercial anticipation, especially in the face of the new generation of neurotechnological devices. Critical examples are precursor wearable devices, such as smartwatches and virtual

[5] Hidden patterns, embedded in application design, are those that use knowledge about human behavior to manipulate users, with the goal of making them stay longer than they would like or exposing themselves more than would be appropriate for their age, for example, constant and flashy notifications, timelines or endless scrolling of content, automatic playback of audiovisual content, use of "likes" or other mechanisms for social or physical appearance comparison.

reality (VR) headsets, which already operate with the recording of brain waves (Mullin, 2025).

In this scenario, it is observed that, like other nations of the Global North (Mullin, 2025), Brazil still lacks robust protection policies, with current safeguards considered weak and insufficiently comprehensive to address these risks. The urgency of an effective regulatory agenda is evidenced by the need to mitigate negative externalities, acting through a synergy of precaution and prevention, that can lead to various lasting brain transformations and generational losses in cognitive skills and critical faculties such as memory and attention.

2. Neurotechnologies

According to the OECD, neurotechnology consists of devices and a set of procedures used to access, monitor, investigate, evaluate, manipulate, and/or emulate the structure and function of the neural systems of individuals (OECD, 2019). In other words, neurotechnology generates profound impacts and can affect, map, and even alter the activity of the human brain. As a rule, the term is used in the plural due to the diversity of its applications and purposes.

In the current state of the art, neurotechnologies are widely used and disseminated in the treatment of mental and neurological diseases, such as Alzheimer's disease, schizophrenia, stroke, post-traumatic stress disorder, major depression, severe compulsions, and especially in addressing addictions (Yuste et al, 2022). Remember that the development of neurotechnologies, combined with the enhancements brought about by new AI modules, has led assistive technologies to endless possibilities for advancement and improvement in the daily lives of people with disabilities and severe disorders. For example, AI can power robotic arms that can be connected to a person's brain or a simple iOS smartphone that can translate written words into spoken words for a visually impaired person (UNICEF, 2018).

It is important, prima facie, to mention that, just as AI is not confused with automation, not all neurotechnology is applied to a brain-computer interface – BCI (or BCI – Brain Computer Interface, in English). Similarly, for a proper understanding of the scope of the impact of neurotechnological applications in relation to the palettes of human and fundamental rights, it is important to understand how they work. In other words, at the heart of so-called neurotechnologies are brain-computer interfaces (BCIs),[6] which are devices that connect the brain to a computer or another device outside the human body, such as a smartphone, for example.

BCIs allow bidirectional communication between the brain and the outside world, exporting data from the brain or altering its activity, and can generally operate in two different ways: 1) Invasive (being inside a person's skull). Cochlear implants or brain stimulators, e.g., which can help people with Parkinson's disease regain mobility, prostheses that make it possible to feel cold and heat, assisting in the treatment of amyotrophic lateral sclerosis (ALS), among others; and 2) Non-invasive (wear-

[6] The opening kick-off of the 2018 FIFA World Cup in Brazil was performed by a quadriplegic person using a robotic exoskeleton controlled by a bioelectrical impedance center (BCI). Olympics with neurotechnology. Available at: <https://www.youtube.com/watch?v=FRKE5C50Emk>.

able) are placed on or outside the body, using an adhesive, a helmet, headbands, or in the form of a ribbon on the head.[7]

It is observed that, in both cases, there is legislative silence from most parliaments and courts (Warat, 1997) in the face of the zeal of large technology companies regarding popularization and trivialization for the purpose of cognitive enhancement, for example. And, in view of this, it should be noted that there are specific gaps in the construction of regulatory arrangements, which are sometimes insufficient or disconnected, and which, in turn, create considerable vacuums in the protection of human rights and fundamental rights (Lopes, 2008). This situation is exacerbated by the possibility of human thought being, to some extent, oversized, altered, decoded or manipulated through the use of neurotechnologies.

At this point, it is pointed out that, through neurotechnologies, it is also possible to generate the intensification of vigilantist (Zuboff, 2020), discriminatory (Rios, 2008) and stigmatizing practices, both state and non-state. In this sense, attention is drawn to the undeniable phenomenon of the exhaustion of the last dimensions of privacy within increasingly technological, racist, polarized, prejudiced, misogynistic, and complex societies (Siqueira and Castro, 2017) as serious risks to the permanence of democratic regimes are perceived.

It is also worth adding that, although the concept of privacy is eminently a bourgeois construct, it is understood that it has become crucial for forging what is known as the subject of law, especially from the perspective of exercising autonomy, the dimensions of freedom and free will which, despite their problematic conceptualization, form the basis of Western society, including legal ones. From this conceptual tangle in crisis emerges the consolidation of the concept of mental privacy.

In truth, although advances in neurotechnologies present unique opportunities that unveil new frontiers of brain function and, therefore, open and will continue to open a vast arena not only for the economy and medicine, but also tending to permeate daily life, it is emphasized, in this sense, the urgency of reflecting cautiously, deeply, and lucidly on the unprecedented implications and externalities that affect the effectiveness of human and fundamental rights.

Incidentally, neurotechnologies have significant potential to expand, improve, and push the boundaries and limits of the human condition, especially in challenging situations such as those involving severe syndromes. However, precisely because it is so radical, it tends to widen inequalities, highlight vulnerabilities, and thus manifest multidimensional challenges unimaginable until now (ICO, 2023).

To situate the importance of the debate regarding neurotechnologies, it is worth recalling that the initiatives were driven by the Obama administration in 2013, which established the BRAIN Initiative in the USA (NIH/USA, 2013), which funded research for the development of neurotechnologies equipped, among other things, with AI modules. Following this trend, countries around the world began to heavily fund similar research projects.[8]

[7] This is considered the main classification, although the ICO, in its report, presented a subclassification of semi-invasive neurotechnologies (ICO. Neurotechnologies: Key definitions. Available at: <https://ico.org.uk/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/technology-and-innovation/ico-tech-futures-neurotechnology/neurotechnologies-key-definitions/>.

[8] See: https://www.braininitiative.org/alliance/.

Thus, neurotechnologies, embedded with increasingly sophisticated AI applications, become a major asset in research and investment for countries like China, the US, and their Big Tech companies that are betting on the hype and use for security purposes, becoming equally profitable within the scope of surveillance capitalism and the attention economy (Yuste, 2024).

Moreover, scientists have already discovered how to use invasive BCIs to investigate clues about the ultimate root of uncritical actions, the itinerary of decision-making processes, the degree of importance of emotionality and brain circuitry, particularly in view of experiments with the brains of laboratory animals. On the other hand, there are major bets on the production of equally powerful portable, wearable, non-invasive technologies.

By way of illustration, a non-invasive BCI does not touch the brain, being placed on a person's head. Wearable brain-computer interfaces (BCIs), such as helmets, glasses, and headbands, can be used to predict behavior or capture a person's intention to move.[9] In reality, they are real-time monitoring and neurostimulation tools, especially when considering the functioning of specific brain areas, and can be used for therapeutic or other purposes. Applications of this kind can be used for disciplining and monitoring the bodies of children, students, and workers, for example. For instance, the case involving the company Emotiv, which generated a legal reaction from the Chilean judiciary, resulted in exemplary punishment.

Indeed, in a pioneering way, Latin America has been paying attention to neurorights, with legislative and jurisprudential development in Chile standing out. In 2021, the country approved an amendment modifying its Constitution to protect brain activity and information related to it.[10] It is also worth highlighting the action of the country's Supreme Court, which decided the first case on the subject. In it, a Chilean citizen sued the company Insight, which sold portable brain monitoring devices in the country. In the end, the Court determined that, in the Emotiv case, the company did not adequately protect the privacy of users and, in practice, enshrined the protection of neurorights.

It cannot be overlooked that, anticipating this, the Neurorights Foundation, in a study released in 2022, analyzed the international gaps in the protection of human rights in the era of neurotechnologies, being, in fact, the first comprehensive review of international human rights law applied to neurotechnologies (Yuste et al, 2022). Certainly, this research served as a warning about advancements in this area, raising alarm bells regarding the risks arising from arbitrariness, abuse, and harmful and thoughtless use.

For a better understanding of this topic, whose implications necessarily evoke the regulation of AI, it is important to focus on the fact that the European Union has undertaken several efforts to establish robust algorithmic governance, particularly through the approval of legislative acts such as the EU AI Act, the Digital Services Act (DSA), the Digital Markets Act (DMA), and the General Data Protection

[9] For example, see the Necomimi device (from NeuroSky Co., Ltd./neurowear) featured in the "Living with Robots" exhibition at Japan House in São Paulo. Available at: <https://www.japanhousesp.com.br/exposicao/convivendo-com-robos/>.

[10] See: https://www.somosiberoamerica.org/pt-br/tribunas/neurodireitos-no-chile-consagracao-constitucional-e-regulacao-das-neurotecnologias/

Regulation (GDPR), which, due to the so-called Brussels effect, serve and will serve as inspiration for other countries.

It is worth noting that, despite what is observed in relation to Chile, most countries are in a state of legislative limbo, which seems to show some resistance due to some parliamentary initiatives such as those attempted in the Brazilian State. Whether due to the unexpected degree of innovation, or in relation to the uncertainty about the appropriate regulatory form to be adopted, the ambiguity of many parliaments around the world regarding neurotechnologies is perceptible and undeniable.

Moreover, as will be detailed below, due to the importance of this agenda and taking into account the absence of specific regulation and assessment of future risks and impacts, the United Nations Committee on the Rights of the Child, in 2021, initiated the discussion through General Comment No. 25 on the Rights of the Child in the Digital Environment (CRC/C/GC/25, 2021).[11]

3. Children's health in the age of artificial intelligence

The Brazilian Society of Pediatrics (SBP), since 2016, when the use of the terminology "artificial intelligence" was not yet widespread, has published studies, warnings, and guidelines for pediatricians, parents, and educators on information and communication technologies (ICTs), social networks, and the Internet and their impacts on the behavioral health of children and adolescents.[12]

In these reports, there is explicit mention of the essential, moral, and legal role of parental mediation throughout the growth and development of children and adolescents, at a time when Internet platforms and AI tools are assuming a preponderant role, due to their constant and widespread use at all ages, becoming a subtle, perverse, and globalized reality. It can be inferred from the document that digital technologies should never replace time and loving, caring, and responsible human contact.[13]

The field of neuroscience already has research results that demonstrate the harmful effects of prolonged screen time, especially the unbridled use of screens for distraction, particularly smartphones, where the attention and engagement industry, promoted by surveillance capitalism, plays a primary role,[14] while AI tools with inter-

[11] See items 96, 98 and 108 to 110 of General Comment No. 25 on the Rights of the Child in the Digital Environment of the United Nations Committee on the Rights of the Child – CRC/C/GC/25.

[12] GUIA Prático de Atualização Grupo de Trabalho: Saúde na era digital – SED@SBP (2019-2021). #Sem Abusos #Mais Saúde. N. 2, 06 de abril de 2021. Sociedade Brasileira de Pediatria. Disponível em: <https://www.sbp.com.br/fileadmin/user_upload/_22969c-GPA-_SemAbusos__MaisSaude.pdf>; GUIA Prático de Atualização Grupo de Trabalho: Saúde na era digital – SED@SBP (2019-2021). #Menos Telas#Mais Saúde. Dezembro de 2019. Sociedade Brasileira de Pediatria. Disponível em: <https://www.sbp.com.br/fileadmin/user_upload/_22246c-ManOrient_-__MenosTelas__MaisSaude.pdf>.

[13] "High screen time among children increases behavioral disorders. As a result, there is a growing demand for treatment in clinics. Symptoms range from irritability and sleep problems to depression. A study by UFMG (Federal University of Minas Gerais) indicates that 30% of children spend more than 8 hours a day in front of screens. With the pandemic, one in four young people is experiencing symptoms of anxiety or depression". Available at: <https://cbn.globoradio.globo.com/media/audio/340226/alta-exposicao-de-criancas-telas-aumenta-transtorn.htm>.

[14] "The persuasive methods used on screens and in apps impact curiosity, screen consumption, and the establishment of digital patterns and habits, influencing early, excessive, and prolonged use, whether out of mere curiosity and impulsivity or due to a lack of discernment, self-regulation, and self-control. Billions are invested in the global entertainment and communication technology industries, and currently, this is being extrapolated to the target audience of children and adolescents as a market niche, which can lead to problematic consumption or develop into

faces and manipulation patterns by design[15] exert a strong influence on children and adolescents in an obscure and unfair way.

Certainly, the consolidation of a technocratic culture in which the appeal to the unreflective and irresponsible use of digital technologies expands, interfering with and impacting areas such as the nervous system, becomes undeniable. In view of this, it is warned that if the mental health of all human beings subjected to such conditions is affected, for human beings still in development, the effect is disastrous,[16] especially in a context marked by inequality.

A central element of the document presented by the Brazilian Society of Pediatrics is the finding that the vulnerability of children and adolescents is associated with the various phases and dynamics of brain and mental development and the sensory circuits of perception of the world. The time of brain development and maturation cannot be "shortened" or even "accelerated" by visual stimuli from screens, but it can be influenced or distorted, with structural alterations of the gray matter in areas such as the prefrontal lobe and the limbic system responsible for emotions, perceptions, and executive functions, and become problematic or create mood disorders and dependence (Brazilian Society of Pediatrics, 2021). In view of this, applications aimed at improving the human species through cognitive enhancement, increased focus, and attention have harmful and irreversible potential in children, especially when devoid of appropriate care and diligence. According to neuroscientist Michel Desmurget (Desmurget, 2021), research director at the French National Institute of Health, today's children "are stunned by silly entertainment, deprived of language, unable to reflect on the world, but happy with their fate." In his book, Desmurget presents, based on concrete data, how digital devices are seriously affecting the neural development of children and young people. "There is simply no excuse for what we are doing to our children and how we are jeopardizing their future and development" (Desmurget, 2021).

According to him, the evidence is palpable: IQ tests have long shown that new generations are less intelligent than previous ones. According to Desmurget, the causes are also clearly identified: a decrease in the quality and quantity of intra-family interactions, essential for language and emotional development; a decrease in the time dedicated to other more enriching activities (homework, music, art, reading, etc.); Sleep disturbance, which is quantitatively reduced and qualitatively degraded; overstimulation of attention, leading to disturbances in concentration, learning, and impulsivity; intellectual understimulation, which prevents the brain from developing its full potential; and excessive sedentary behavior which, in addition to affecting physical development, influences brain maturation (Desmurget, 2021).

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future behavioral dependencies." (GUIA Prático de Atualização Grupo de Trabalho: Saúde na era digital – SED@ SBP (2019-2021). #Sem Abusos #Mais Saúde. N. 2, 06 de abril de 2021. Sociedade Brasileira de Pediatria. Available at: <https://www.sbp.com.br/fileadmin/user_upload/_22969c-GPA-_SemAbusos__MaisSaude.pdf>).

[15] See:https://www.forbes.com/sites/federicoguerrini/2024/11/17/ai-driven-dark-patterns-how-artificial-intelligence-is-supercharging-digital-manipulation/.

[16] Numerous warnings have already been issued. For example: <https://www.ime.usp.br/~vwsetzer/efeitos-negativos-meios.html>; <http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S0104-12822020000300005&lng=pt&nrm=iso&tlng=pt>; <https://www.revistaencontro.com.br/canal/revista/2020/03/neuropediatra-afirma-que-ha-aumento-real-na-incidencia-de-autismo.html>; <https://www.neurologica.com.br/blog/neuropediatra-explica-os-riscos-do-uso-excessivo-de-celular-e-computador/>; <https://cangurunews.com.br/filho-celular-pandemia-digital/>.

Furthermore, it warns that screens cause damage to the neurological system, as the brain is not a "stable" organ. Its "final" characteristics depend on life experience. The world in which one lives, the challenges faced, modify both its structure and its functioning, and some regions of the brain specialize, some networks are created and strengthened, others are lost, some become denser and others thinner.

In convergence, the Committee of Ministers of the Council of Europe warned, in 2019, in its "Declaration on the manipulative capabilities of algorithmic processes",[17] that "detailed, subconscious and personalized levels of algorithmic persuasion can have significant effects on the cognitive autonomy (Joaquim and Pesce, 2025) of individuals and on their rights to form an opinion and make independent decisions". The Committee also acknowledges that "these effects remain unexplored, but should not be underestimated".

Similar concerns are raised about the consequences of practices adopted by public actors, such as the use of facial recognition technology and other monitoring mechanisms, e.g., in schools, clubs, and other educational environments (ANPD, 2024). For example, the Swedish Data Protection Authority fined a municipality for using facial recognition technology to monitor student attendance in schools without complying with the EU General Data Protection Regulation (GDPR). In addition to violations of obligations regarding the protection of personal data increasing in constantly monitored environments—where movements, behaviors, and relationships are tracked—a negative long-term effect on children can also be foreseen (Lievens, 2021).

It is understood that, in principle, facial recognition cameras can leave children feeling intimidated and stressed, consequently producing a sense that they are being constantly observed and subjected to incessant monitoring. This creates a panoptic environment where children feel and are always under supervision because they are typically suspected of supposedly disapproved behaviors. Such mechanisms alter how children identify themselves, recognize themselves, socialize, and interact (UC Berkeley, 2019). In fact, an artificial atmosphere, devoid of spontaneity, is forged in which children are, for example, unable to have private conversations at school with their peers or teachers.

Given this, it cannot be overlooked that the excessive screen time of young people,[18] as well as early use under the appeal of harmlessness or even the idea that it would enhance cognitive skills, actually involves risks and harmful impacts, while several studies support the idea that the existence of the "digital native" is a cleverly constructed myth (Desmurget, 2021).

With this in mind, the question arises: do children already possess all the cognitive tools and critical thinking to interact directly and uninterruptedly with

[17] The Committee of Ministers of the European Union adopted, on February 13, 2019, at the 1337th meeting of Deputies of Ministers, the Declaration on the manipulation capabilities of algorithmic processes. In order to corroborate the Committee's conclusions, the OECD published five basic principles for regulating AI. Available at: <https://www.oecd.org/going-digital/forty-two-countries-adopt-new-oecd-principles-on-artificial-intelligence.htm>.

[18] High screen time for children increases behavioral disorders. As a result, demand for treatment in clinics is growing. Symptoms range from irritability and sleep problems to depression. A study by UFMG (Federal University of Minas Gerais) indicates that 30% of children spend more than 8 hours a day in front of screens. With the pandemic, one in four young people is experiencing symptoms of anxiety or depression. Available at: <https://cbn.globoradio.globo.com/media/audio/340226/alta-exposicao-de-criancas-telas-aumenta-transtorn.htm>.

AI-embedded digital technologies? How can they be empowered to live and build an environment in which their human and fundamental rights are respected, protected, and promoted? How can they be protected and strengthened when there is a risk that responsible use will be violated to the detriment of their life projects? Are children's mental health and cognitive abilities at risk in the face of a technocratic culture that invests in discrimination, hierarchy, and enhancement practices, especially in unequal and peripheral countries like Brazil? What would be the main instruments of governance, data management, and regulation of digital technologies, including those applicable to the central nervous system, compatible with the range of human and fundamental rights of Brazilian children? These are some of the questions that this work aims to address, especially from the perspective of the ECA (Brazilian Statute for Children and Adolescents) and Law No. 15.211/2025, recognized as the Digital Statute for Children and Adolescents ("Digital ECA").

3.1. Mapping the brazilian landscape of child protection

According to the 2024 Global Digital Report,[19] Brazil is the second country where users spend the most time online, with an average of 9 hours and 13 minutes, behind only South Africa with 9 hours and 24 minutes. Given this context, the age limit[20] tends not to be respected by platforms and social networks, allowing children to use and have profiles on the main networks – WhatsApp, Facebook, YouTube, Instagram, TikTok – at a very young age, when the age limit in the terms of use is, on average, 16 years for WhatsApp and 13 years for the other networks.

Regarding AI, Generative AI is already part of the routine of more than a third (32%) of Internet users in Brazil, which, in absolute numbers, is equivalent to about 50 million people aged 10 or older, according to data from the 2025 ICT Households Survey, in which generative AIs already interact with children in their daily lives. When mentioning the best possible use, it should be considered that this premise must be imbued with the notion of respecting the best interests of the child in the development, marketing, and use of new digital technologies that impact this audience.[21]

This perspective of technological overexposure should also be observed in perspective with the acute social inequality in the country, which generates perverse effects in the field of education – educational, food, and health deficits. It is important to state that the use of digital technologies structures and exacerbates socioeconomic divisions, including taking into account the type of device accessed (computer, tab-

[19] Report published in partnership between We Are Social and Meltwater, available at: <https://wearesocial.com/uk/blog/2024/01/digital-2024-5-billion-social-media-users/>.

[20] Approximately 83% of internet users aged 9 to 17 had their own profile on at least one of the digital platforms investigated, with 60% for the 9-10 age group, 70% among those aged 11-12, and 93% for those aged 13-14. Among the oldest (aged 15 to 17), almost all (99%) had a profile on at least one digital platform. (Internet Steering Committee. Information and Coordination Center of the .BR Domain. TIC Kids Online Brazil Survey – 2024. São Paulo. Cetic. Available at: <https://cetic.br/pt/publicacao/pesquisa-sobre-o-uso-da-internet-por-criancas-e-adolescentes-no-brasil-tic-kids-online-brasil-2024/>).

[21] Available at: <https://www.cgi.br/noticia/releases/50-milhoes-de-brasileiros-ja-usam-ia-mas-potenciais-beneficios-continuam-limitados-as-camadas-de-maior-renda-e-escolaridade/#:~:text=renda%20e%20escolaridade-,50%20milh%C3%B5es%20de%20brasileiros%20j%C3%A1%20usam%20IA%2C%20mas%20potenciais%20benef%C3%ADcios,de%20maior%20renda%20e%20escolaridade&text=%E2%80%9CA%20TIC%20Domic%C3%ADlios%202025%20destaca,os%20usu%C3%A1rios%20de%20Internet%20brasileiros>.

let, smartphone), usage time, and the existence or not of parental supervision. It is worth noting that this situation becomes more pronounced with regard to the use of neurotechnologies.

This is a complex situation whose pacification regarding risks and effects, in Brazil, has already resulted in the prohibition of smartphones in schools in 2025[22] in order to preserve the integrity and mental, physical and psychological health of children and adolescents, by restricting the use of cell phones in schools for students of all stages of basic education, during classes, breaks and recess.

In addition, when investigating the repercussions of the digital age on human life and human rights violations, it is urgent to understand that the potential to negatively impact the most vulnerable populations has the power to deepen social inequalities,[23] especially in developing countries, involving what has been identified as data colonialism (Couldry and Mejias, 2019), as it deepens the learning divide in society, keeping the populations of these countries unaware of the beneficial potentials of innovation, not being included as real actors generating knowledge, but rather mere consumers and, at best, labor of the system, reproducing extractive colonial practices, only now at the cost of mental health.

At this point, Brazil is already moving towards becoming an extensive database for large technology companies,[24] given that the school environment already uses tools and systems from large technology companies, and even the largest public universities in the country have been incorporated into this logic.[25] To give an idea, the TIC Kids Online Survey revealed that, in 2024, approximately 24.5 million people aged 9 to 17 were internet users in Brazil (93%) (CGI/NIC.Br, Brazil, 2024). Many children have access to tablets and smartphones before they learn to walk and talk.

There is a need to pay attention to the algorithmic impact, particularly the "technosocial impacts" (Dallasta, 2025), which should be understood as collectively generated, with the potential to restructure human coexistence and life in the long term,

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[22] Law No. 15.100/2025, regulated by Decree No. 12.385/2025, of February 19, 2025, which provides for the restriction of the use of personal portable electronic devices in schools. The objective is to establish the restriction of these personal devices for students during classes, recess, or breaks, at all stages of basic education. Available at: <https://agenciagov.ebc.com.br/noticias/202502/publicado-decreto-que-regulamenta-uso-de-celular-na-escola>.

[23] "The second digital divide is real: pupils from more privileged backgrounds tend to have greater digital skills. Special efforts must be made to overcome these inequalities and ensure that disadvantaged children receive the support and guidance they need to succeed in a digital world (Hatlevik, Guðmundsdóttir and Loi, 2015). OECD Report. Available at: <https://vdocuments.net/what-do-we-know-about-children-and-technology-suggests-that-preschoolers-become.html>."

[24] Facebook Papers documents expose Brazil under attack. Brazil is classified by the company as a "high-risk country" with the potential for mass violence. (...) Addiction to the social network. Despite the problems, many citizens of the country feel sucked in by Mark Zuckerberg's products. The report found a company survey that measured, in 2019, the quality of Brazilians' relationship with the platform. In the file, there are accounts from Brazilians about being addicted to the social network – one of them even compares Facebook to alcoholic beverages. "When you have a beer on the weekend, you drink it. You need to drink. It's the same thing with Facebook," he says. "The time I spend on Facebook is not healthy, it's like an addiction. I keep opening the app every half hour, it's not healthy," says another user. (...) Regarding toxic content, the company says it reduced by more than half the amount of hate speech posts that people see on the platform last year, globally. (...) Regarding social media addiction, the company reproduced a text by Nick Clegg, vice president of global affairs and communication. "Research on the impacts of social media on people is still relatively nascent and evolving, and the platforms themselves are changing rapidly. Some researchers argue that we need more evidence to understand the impact of social media on people." Available at: <https://duality.com.br/documentos-do-facebook-papers-expoem-brasil-sob-ataque/>.

[25] Available at: <https://educacaovigiada.org.br/>.

in a non-democratically deliberate way. These impacts stem from the technical applications of AI without prior consideration of their social consequences, which is why the term "techno" precedes "social." Recognizing such social impacts is crucial due to the absence of protections against potential structural harm. This is an area where there is an urgent need for robust research.

Therefore, aiming at the effectiveness of the rights of personal agency and human autonomy for future generations, the existence of precautionary mechanisms applicable to artificial intelligence in the Digital ECA (Law No. 15,211 of 2025) and in Resolution No. 245/2024, of the National Council for the Rights of Children and Adolescents – Conanda, of April 5, 2024, is analyzed, which assigns to the Public Authorities, families, society and companies the responsibility for guaranteeing and implementing the rights of children and adolescents in the digital environment.

Regarding the recent Digital ECA, the only express mention of the terminology "artificial intelligence" in the Digital ECA is found in art. 17, §4, item VIII ("VIII – regular review of artificial intelligence tools, with the participation of experts and competent bodies, based on technical criteria that ensure their safety and suitability for use by children and adolescents, guaranteeing the possibility of disabling functionalities that are not essential to the basic operation of the systems;").

Regarding the monitoring of "impacts," the document states the following in Article 8: "Article 8. Suppliers of information technology products or services aimed at children and adolescents or likely to be accessed by them must: I – conduct risk management of their resources, functionalities, and systems and their impacts on the safety and health of children and adolescents;".

In relation to the primary mechanism for making products available on the market, namely the monitoring of impacts associated with the technologies used, the law establishes the following guidelines in Articles 16 and 31: Article 16 establishes that suppliers of technologies aimed at or accessible to children and adolescents must provide clear information on risks and security measures, including privacy and data protection, independently of the acquisition of the product. In the case of data processing that goes beyond the strict operation of the service, the controller is obliged to map and mitigate risks, in addition to preparing impact and monitoring reports that may be requested by the competent administrative authority. This transparency aims to ensure compliance with the LGPD (Brazilian General Data Protection Law) and the best interests of children and adolescents in the face of AI mechanisms and hidden patterns that may induce harmful uses.

Article 31 imposes additional obligations on providers with more than one million users in this age group, requiring the semi-annual publication of reports in Portuguese detailing reporting channels, moderation volume, and measures for identifying children's accounts. These reports must present the results of health and safety impact assessments, as well as technical improvements for parental consent and privacy. Additionally, the rule ensures free access to data for academic and journalistic research on the impacts of these services, prohibiting the commercial use of this information and safeguarding the principles of confidentiality and security.

Regarding the potential techno-social impacts of a collective nature, the Digital ECA stipulates the consideration of the "impact on the community with regard to the flow of information in the national territory," in the provision for the gradation of the

application of sanctions for non-compliance provided for in the law (art. 35, §1, item IV), without mentioning collective impacts on public health, for example.

Furthermore, consider the issuance of Decree No. 12,622, of September 17, 2025, which regulated Law No. 15,211, of September 17, 2025, to designate the National Data Protection Agency (ANPD) as an autonomous administrative authority for the protection of children and adolescents in digital environments, and to establish competences for compliance with judicial blocking orders.

Regarding CONANDA Resolution 245, Chapter V stands out, which deals with the duty of care and responsibilities of companies providing digital products and services. It emphasizes that companies providing digital products and services used by children and adolescents, operating in Brazil, including those based abroad, are responsible for implementing and guaranteeing the rights of this public in the digital environments they produce and regulate. The codes of conduct of technology companies must include guidelines on how to report risks and suggest improvements for the protection of the rights of children and adolescents. Therefore, effective age verification mechanisms in digital services and environments accessible to children and adolescents must be made available to prevent children and adolescents from accessing platforms, products, services, and content that are illegal or incompatible with their age.

This device addresses the ongoing debate, including internationally, regarding corporate responsibility for disregarding terms of service and weak or non-existent age verification for access to products and services not intended for children, which are widely and unrestrictedly accessed by them, to the detriment of their mental and emotional health.[26]

In a very practical way, Article 22 of the Resolution states that service provider companies are responsible for proactively and diligently identifying, measuring, evaluating, and mitigating real or foreseeable risks to the rights and best interests of children and adolescents related to the functionalities, design, management, and operation of their services and systems, including the algorithmic systems of social networks, games, applications, and other digital environments, especially those related to: mental health, such as addiction, excessive screen time, and potential harm to the self-esteem and physical and emotional well-being of children and adolescents; violation of the right to family and community life; dissemination of harmful, damaging, and illegal content in digital services and environments; direct or indirect discrimination resulting from algorithmic systems or the use of sensitive personal data, due to personal characteristics, especially race, color, ethnicity, gender identity, sexual orientation, disability, age, origin, philosophical, political, or religious beliefs, or any particularity or condition;

It should be noted that Article 22 of the Resolution states that Article 28 of the Resolution stipulates that, for the purposes of compliance with the national legal sys-

[26] It is important to mention that services that do not respect their own age restrictions harm the protection of children. According to research, 25% of ten-year-olds and 43% of eleven-year-olds who access the internet have a profile on social networks, despite the minimum age of 13 for most social networking sites. "A popular application that allows video chat between random users automatically fills in the user's age as 18 at the time of registration. Underage users are able to access the application without additional verification." Available at: https://www.riskyby.design/friend-suggestions. Accessed on May 5, 2024.

tem, companies must publish, at least annually, reports on: Transparency, regarding the operation of their services and systems, including algorithmic ones, as well as the use of data collected during the operation of their services.

The implementation of the new regulatory framework requires digital platforms to establish rigorous governance measures from the conception and development of their systems, with meticulous detailing of methods aimed at preventing and mitigating risks. This commitment extends to the clear disclosure of sanctions applicable to offenders and to continuous efforts to educate and promote the conscious, healthy and responsible use of digital services.

Fundamentally, the rule imposes an updated risk assessment that prioritizes the best interests of children and adolescents even before the introduction of new functionalities, always observing the specificities of the Brazilian context. To ensure the effectiveness of these safeguards, it is mandatory to conduct independent audits that attest to compliance with the legal framework and strict adherence to the Duty of Care established by the legislation in force in the national territory.

Regarding mobilization and awareness-raising actions on the impact of the digital environment on children and adolescents, the Public Authorities and companies providing digital products and services must carry out awareness-raising actions on the rights and risks to children and adolescents in the digital environment, focusing particularly on sectors whose practices have a direct or indirect impact (art. 29).

And §3 of art. 29 establishes that professionals who work directly or indirectly for or with children, including in the technology industry, must receive training on the impact of the digital environment on the rights of children and adolescents, the exercise and protection of the rights of this public, and the identification of risks of violation and victimization of children and adolescents in the digital environment. Thus, in addition to including topics such as protection, transparency, commercial exploitation, freedom of expression, right to privacy, data protection and responsibility of technology companies, Resolution No. 245/2024 proposes the development of a national policy for the protection of the rights of children and adolescents in the digital environment, to be developed within ninety days of its publication.

It should be noted that CONANDA is the main body in the system for guaranteeing the rights of children and adolescents in Brazil. Composed of thirty members, it brings together representatives of the government and civil society. Thus, it defines the general policies and standards for this area, monitors compliance with actions carried out by the public authorities with regard to serving the child and adolescent population, supports state and municipal councils for the Rights of Children and Adolescents, and promotes public campaigns (CONANDA, Brazil, 2024).

In addition, as the UNICEF consultation refers to, and the CONANDA Resolution makes imperative, this is also an important moment for technology companies to advance and share examples of best practices to make the digital environment a place that is more respectful of children's rights. In practice, this denotes that there is no absence of theoretical and rhetorical guidelines, but that effective practical efforts to provide better results for children, broadly guaranteeing their rights and primary consideration, as is due, still lack full integration into robust Due Diligence processes (OHCHR, 2022). In this sense, the Conanda Resolution represents an important step in this process, at the national level.

Finally, but no less importantly, the absence of robust regulation for AI exposes vulnerable groups, such as women and children, to severe harm, exemplified by the Grok platform scandal in 2026, which allowed the large-scale production of deepnudes without consent. To mitigate these risks, Bill 2338/2023 proposes classifying the manipulation of synthetic images of minors as a case of excessive risk, imposing an absolute ban even for recreational or artistic purposes. This measure aims to align technological development with the Statute of Children and Adolescents (ECA), specifically combating the materialization of foreseeable risks that violate the dignity, privacy, and psychosocial development of subjects in a peculiar condition of development.

In convergence, the legislative proposal establishes rigorous governance obligations, such as the duty to disclose risks and limitations, in addition to the mandatory identification of synthetic content generated by AI, such as deepfakes and deepnudes. The supervisory structure should include a network of popular participation and coordinated institutional articulation between data protection authorities, the justice system, and child protection agencies. By requiring independent audits and algorithmic impact assessments, the aim is to ensure that the "Duty of Care" is observed by companies, preventing technological innovation from resulting in algorithmic discrimination or irreversible damage to fundamental rights.

Final considerations

The use of neurotechnologies and AI should not be seen as a phenomenon of technological inevitability, but as a field that requires urgent regulation to safeguard, e.g., the free development of personality and informational self-determination. The absence of safeguards in already commercialized mechanisms exposes children and adolescents to risks that transcend the biological sphere, affecting what the Inter-American Court of Human Rights defines as a "life project": the right to live with dignity, autonomy, and purpose in life.

When AI atrophies human potential through hidden patterns or algorithms that make dialogue and social trust impossible, it promotes a dehumanization that can generate irreparable psychological and emotional damage, compromising the expectations of personal and family development of future generations.

Given the current technocratic mentality, the implementation of technological, critical, and ethical literacy from the early grades of elementary school becomes essential. Education can act as the central axis of a protective strategy, empowering students to understand that technologies are not neutral and that generative AI systems operate, e.g., as "mirrors" that can dangerously shield young people emotionally. It is urgent to equip children and adolescents with the notion of meta-analysis — the ability to decide what will be delegated to the machine and what will remain under total human control — ensuring that intelligence, memory, and sociability do not suffer lasting brain transformations resulting from unregulated environments.

In light of this, governance is needed that prioritizes untranslatable human sensitivity and civilizational values over technological cynicism. Although the new Digital ECA (Law 15.211/2025) places Brazil in a leading position in the protection of children and adolescents, the full effectiveness of this instrument depends on

investments in cognitive capacity and the healthy brain development of individuals, as stipulated by the UN Convention and international jurisprudence. Collaboration between humans and machines will only be ethical and socially conscious if there is an unwavering commitment to preventing the artifice from turning against the artificer, ensuring the fulfillment of the "duty of care" and, consequently, the integrity of human life in all its complexity.

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Cognitive offloading and the right to cognitive freedom: an analysis of the risks of generative AI to the neurodevelopment of children and adolescents

PATRÍCIA MOURA MONTEIRO CRUZ[1]

RENATO VILARDO DE MELLO CRUZ[2]

ANTONIO JORGE PEREIRA JÚNIOR[3]

Introduction

The emergence of generative artificial intelligence, particularly large language models such as ChatGPT, released in 2022, has produced an unprecedented transformation in the relationship between humans and cognitive technologies. Unlike earlier technological tools, which served as passive repositories of information or search engines, modern generative systems are capable of producing texts, solving mathematical problems, constructing legal arguments, and even simulating reasoning processes with remarkable precision.

This technological capacity of generative artificial intelligence (AI) does not merely facilitate human intellectual work; it can also replace it in dimensions that until recently were considered exclusively human. The phenomenon becomes even more concerning when children and adolescents are regarded as among the most

[1] Master's and PhD Candidate in Constitutional Law at the University of Fortaleza. Scholarship Holder and Professor of Undergraduate and Postgraduate *Lato Sensu* in Law at UNIFOR. patriciamoura@unifor.br

[2] Master's Student in Law and Conflict Management at the University of Fortaleza. State Attorney of Ceará and Lawyer. renatovmcruz@gmail.com

[3] Full Professor of the Master's and Doctoral Program in Constitutional Law at the University of Fortaleza. Doctor, Master's, and Bachelor's degree in Law from USP. Winner of the Jabuti Prize 2012, Law category. antoniojorge2000@gmail.com

enthusiastic users of this technology. The adoption of generative AI tools in educational settings has grown exponentially since the launch of ChatGPT, often without adequate pedagogical mediation and without regulatory frameworks to protect the most vulnerable, who are still in critical phases of physical and intellectual formation.

This research adopts a qualitative, exploratory, and bibliographic methodology, with an interdisciplinary approach drawing on a literature review in the fields of developmental neuroscience, neuroethics, cognitive psychology, and constitutional law. To achieve its stated objective, the study examines the impacts of generative AI tools on the cognitive processes of children and adolescents. The legal analysis employs the hermeneutic-constitutional method, examining the compatibility of neurorights with Brazilian legislation on the comprehensive protection of children and adolescents.

Given that legal answers are frequently sought in other fields of knowledge, it is important to explore the possibility of approaching law through the lens of Neuroscience (Ferreira, 2020). In this regard, neuroscience plays an extremely important role in the scientific debate by more clearly identifying the risks to which children and adolescents are exposed, including the potential threat to the human dignity of the most vulnerable (Cruz and Pereira Júnior, 2022).

This study aims to analyze the implications of generative artificial intelligence as it systematically takes over cognitive tasks essential to child and adolescent development, such as reading, interpretation, writing, logical reasoning, and problem-solving, in order to investigate whether this tool operates as a cognitive offloading mechanism capable of undermining the neurological formation of children and adolescents during critical periods of neuroplasticity. If such harm is confirmed, the study further investigates whether this interference by generative AI can be legally characterized as a violation of the right to cognitive freedom, considered one of the proposed fundamental neurorights.

Both hypotheses raised above are confirmed in this article. It is argued that cognitive offloading, mediated by generative AI, when used prematurely, systematically, and without restrictions on neurologically developing users, does not constitute mere technological assistance, but rather a structural interference in the process of autonomous cognitive formation, one that amounts to an affront to the right to cognitive freedom, which guarantees that every person may develop and exercise their mental capacities without unconsented external interference.

Regarding the structure of the article, it begins by addressing the theoretical foundations of cognitive offloading and its developmental trajectory in childhood. It then examines how generative AI represents a qualitative shift in offloading mechanisms and the consequences of early and systematic offloading on the developing brain. Next, neurorights are analyzed along with the ways in which cognitive offloading may constitute a violation of the cognitive freedom of children and adolescents. Finally, available normative frameworks are presented, along with proposed instruments to ensure legal protection for the vulnerable.

1. Cognitive offloading and its development in childhood

Cognitive offloading can be defined as the use of tools capable of altering information processing requirements in order to reduce internal cognitive demand, that is, physical action diminishes the mental effort required to perform a given task. This externalization of mental processes is used by humans to compensate for the biological limits of unaided cognition, ranging from entering an appointment in an application to delegating problems to a computational system (Risko and Gilbert, 2016).

There are different forms of mental externalization depending on the motivation for their use, such that there are two main modalities of cognitive offloading: intention offloading and belief offloading. Gilbert *et al.* (2022) propose the concept of intention offloading, which consists of the use of external tools guided by metacognitive processes rather than automatic delegation. This modality of offloading involves a strategic choice oriented by the individual's assessment of their own memory capacity. In this form of externalization, healthy offloading presupposes a functional metacognitive apparatus, which is still under construction in childhood.

In the form of belief offloading, the externalization is deeper and more complex: the person delegates to the tool the task of thinking, evaluating, and deciding (Guingrich, Mehta and Bhatti, 2026). This modality transcends traditional forms by describing the externalization not only of information or intentions, but of the very formation and maintenance of beliefs. In this form of externalization, the individual does not merely delegate the task of remembering or calculating, but the very act of reasoning and deciding what to believe. This modality is particularly relevant to legal analysis, as it shifts the problem from the realm of cognitive efficiency to the field of epistemic autonomy and, ultimately, of freedom of thought itself.

The decision to offload these functions depends on several variables, such as the perceived difficulty of the task, the individual's metacognitive confidence in their own ability, and the level of effort required to access the external tool. With regard to the internal, psychological motivation for cognitive offloading, the empirical demonstration by Boldt and Gilbert (2019) reveals that low subjective confidence in one's own memory, rather than the individual's actual capacity, is the main trigger for inappropriate delegations.

According to Chiu and Gilbert (2024), the external, environmental motivator for offloading would be the mere reduction of the physical effort required to set up digital reminders. The facilitating design of technology, as is the case with generative AI, converges to drive a pattern of excessive dependence, even when offloading is not necessary.

In order to understand the phenomenon, it is necessary to recognize that cognitive offloading is not a static phenomenon, but rather a capacity that develops throughout childhood in accordance with trajectories that reflect the maturation of executive and metacognitive functions.

Based on a study conducted with 150 children aged between 4 and 11 years, Bulley *et al*. (2020) demonstrated that children are capable of spontaneously creating and selectively using tools to offload cognitive tasks, adjusting their strategies to the difficulty of the task. However, the sophistication of this capacity varies significantly

with age: younger children aged 4 and 5 readily use offered strategies but rarely create their own; older children aged 10 and 11 demonstrate the ability to create offloading strategies tailored to specific demands. These research findings suggest that sensitivity to reasoning difficulties emerges early in development and improves throughout the first years of schooling.

Another study with 258 children aged 4 to 11 conducted by Armitage, Bulley and Redshaw (2020) indicates that even children aged 4 and 5 possess some level of metacognitive awareness regarding the difficulty of mental rotation, calibrating their offloading decisions according to the task demands. The research results suggest that plasticity during critical windows of development allows for the customization of offloading strategies, but also creates vulnerability to disruptive patterns when exposure to tools is not appropriately managed.

With the aim of reviewing research on the development of cognitive offloading, Armitage and Gilbert (2025) presented a study on young people's responses to unprecedented exposure to increasingly advanced technological aids. The authors observed that children from the age of 4 demonstrate cognitive offloading capacity, but with systematic biases.

These younger children exhibit inadequate or excessive offloading, a lack of selectivity, and an absence of self-initiative, traits that are only progressively overcome around the ages of 10 and 11. The capacity to evaluate one's own cognitive limitations, known as metacognition, develops gradually from the age of 3 to approximately 12 years and constitutes the primary mechanism that allows individuals to decide when to offload and when to invest in internal cognitive resources.

Research findings indicate that if offloading depends on a developing metacognitive apparatus, the early and unrestricted provision of tools that eliminate the need for mental effort, as is the case with generative AI, may undermine the very development of that apparatus, thereby creating a vicious cycle in which the ease of offloading prevents the formation of the capacity needed to decide when to offload.

Cognitive offloading presents a genuine dilemma: it improves the immediate performance of its users but may undermine learning in progress and long-term retention. Modern technological tools are capable of increasing immediate task performance while simultaneously reducing accuracy in surprise memory tests, as demonstrated by experiments conducted by Grinschgl, Papenmeier and Meyerhoff (2021).

Highlighting the fact that cognitive offloading increases immediate performance on one hand while diminishing subsequent memory performance on the other, Grinschgl and Neubauer (2022) emphasize that educators must prepare students to distinguish between their own knowledge and externally stored knowledge, a distinction that becomes increasingly blurred with the growing use of generative AI.

The experiments point to direct consequences for children's educational performance: children who use generative artificial intelligence to complete school tasks without understanding that the goal is to learn, not merely to finish a task, may be trading immediate performance for learning deficits. Without the metacognitive awareness to understand this tool, the child becomes trapped in a cycle of false high performance and low levels of actual learning.

2. Generative AI in cognitive offloading and neurological and behavioral impacts on young users

The interaction between human cognition and external cognitive tools is not a recent phenomenon: over time, innovations such as the invention of writing, the use of calculators, and digital search engines have been continuously redefined and refined to assist with proposed tasks. However, generative AI imposes a qualitative break with this pattern and distinguishes itself from all previous tools, owing to the type of process it externalizes.

This is because, rather than merely transferring the burden of memorization, basic mathematics, or data retrieval, generative AI delegates intellectual production itself, including writing, interpretation, reasoning, problem-solving, argumentation, and decision-making. Klein and Klein (2025) characterized this shift through the concept of the "hollowed mind," arguing that AI allows users to avoid the mental effort necessary to build deep and resilient knowledge. The very capabilities that make AI a widely used cognitive tool are those that allow users to circumvent the effort required for the formation of internal knowledge. The authors call this phenomenon the "sovereignty trap", a process of progressively increasing delegation of cognitive functions to AI that gradually undermines a person's ability to exercise sovereignty over their own thought processes.

Drawing on Kahneman's theory, Chiaratti *et al.* (2025) proposed the concept of "System 0" to describe AI as a cognitive processor that shapes information before the human brain actively engages with the task. This dynamic becomes even more alarming when applied to children, for if AI acts as a pre-processor that molds the conditions under which cognition unfolds, the child loses not only the final product of thought, but also the opportunity to exercise and develop their own reflective capacities.

Barandiaran and Pérez-Verdugo (2025) introduce the term "midtended cognition" to refer to the hybrid mental dynamic that arises from continuous interaction with AI systems that are neither entirely internal nor entirely external. The integration of human mental processes and artificial intelligence operates in an intermediate space, creating a zone of indistinction that is particularly problematic for children and adolescents, who are still constructing their notions of intellectual authorship and epistemic identity.

The body of empirical evidence on the effects of generative AI on the human mind is expanding rapidly. In a study conducted by Kosmyna *et al*. (2025) using electroencephalography (EEG) assessed the brain functioning of individuals writing with and without ChatGPT support. The results reveal that people who use AI exhibit lower neural activation and a reduced sense of ownership over the texts produced. The authors coined the concept of "cognitive debt" to describe the continuous deterioration of autonomous reasoning capacity driven by habitual AI dependence.

A study conducted by Gerlich (2025) involving 666 participants revealed that frequent AI use for cognitive tasks is associated with a reduction in independent critical thinking, particularly among younger users. The studies demonstrated that generative AI induces what the literature conceptualizes as "cognitive laziness": users give

up more quickly on difficult problems, invest less effort in independent solutions, and develop less intellectual resilience.

An experiment conducted at Corvinus University of Budapest sought to investigate the impacts of generative AI on the learning process. The study divided students into two groups, one with unrestricted access to AI and another without. It was found that the use of AI tools improves immediate grades but reduces knowledge retention by approximately 30% and significantly undermines the ability to apply acquired knowledge in new contexts (Benedek and Sziklai, 2025).

Regarding the impact of regular AI use by adolescents in educational settings, studies reveal impairment in the development of critical thinking during the most sensitive developmental window. Dependence can be established in approximately three months of regular use without pedagogical intervention. A study conducted with 744 adolescents aged 12 to 17 found that the adoption rate of generative AI tools, specifically ChatGPT, was 52.6% among students. A concerning pattern was also identified: adolescents with less developed executive functions are precisely those who use generative AI tools the most, thereby creating a vicious cycle of offloading and cognitive underdevelopment (Klarin *et al.*, 2024).

Beyond the traditional cognitive impacts related to memory, critical thinking, and attention, even deeper mechanisms of impairment can be identified. The externalization of belief formation to AI systems represents a distinct threat, as it compromises not only cognitive efficiency, but also the epistemic autonomy of the user.

Thus, in children, whose belief systems are still under development, AI co-participation may mean that fundamental parts of their epistemic identity will be shaped not through experience and reflection, but rather by *outputs* algorithmic outputs.

Chirayath, Preramalini and Joseph (2025) argue that AI profoundly reshapes not only everyday life, but the very strategies people employ to cope with mental and emotional obstacles. For this reason, the authors advocate for careful technological design so that the tool can promote resilience rather than generate user dependence. They highlight three main threats posed by AI use: the reduction of introspective capacity, the delegation of resilience to external factors, and the anxiety generated by hypermonitoring, vulnerabilities that, in children and adolescents, affect cognitive capacities that are still being formed.

It is also necessary to consider the serious risks generated by the so-called "hallucinations" of generative AI. According to Osler (2026), "hallucinations", factually incorrect information generated with an appearance of reliability, can become integrated into the user's mental ecology, creating false memories and beliefs. In children with less critical capacity, these distortions threaten to definitively contaminate the knowledge base that is still being formed.

Regarding the harms of technological dependence, Dergaa *et al.* (2025) coined the term AICICA (*AI-Cognitive Interference and Cognitive Atrophy*) to define the systematic mental degradation associated with excessive AI use. The concept identifies the progressive nature of the process, since the harm is not immediate but cumulative. It is not, therefore, a single event, but an atrophy that sets in gradually as cognitive functions cease to be exercised.

Just as muscular atrophy, in which the absence of movement weakens physical tissue, the abstention from mental exercise can lead to permanent cognitive losses. This weakening of cognitive capacity may be irreversible, especially in the case of children and adolescents, given their sensitive phase of neurological maturation.

3. Childhood neuroplasticity and the consequences of early and systematic offloading

The principal feature that distinguishes the child's brain from that of the adult is neuroplasticity, understood as the capacity to reorganize synaptic connections in response to experience. This property reaches its peak during childhood and remains elevated throughout adolescence. This plasticity simultaneously represents the greatest strength and the greatest vulnerability of the developing brain.

Neuroplasticity enables the rapid acquisition of knowledge and skills, and also makes the brains of children and adolescents more susceptible to patterns of stimulation that can alter developmental trajectories and generate irreversible impacts.

More than a static structure, the brain not only produces new neurons but actively responds to environmental stimulation through experience-dependent modifications, constituting what has been called intentional plasticity (Relvas, 2015). This intrinsic relationship between stimulus and experience forms the physiological basis of learning, so that the early introduction of AI tools acts directly as an environmental factor that shapes, or, in the case of systematic offloading, deprives the brain of, the formation of these fundamental connections.

Thus, the adequate exploitation of windows of opportunity and critical moments of development becomes indispensable for sensory and cognitive stimulation, which form the pillars of effective learning (Relvas, 2015). Although the central nervous system maintains a certain degree of plasticity in adult life, as noted, it is during childhood that the response to stimuli reaches its peak of structuring. Consequently, when a generative AI system replaces the cognitive effort required for problem-solving during these critical windows, the active experience necessary to strengthen the neural pathways associated with autonomous reasoning is suppressed, potentially compromising the neurological architecture still being formed.

Drawing on an analysis of algorithmic biases and adolescent neurorights, Muñoz and Marinaro (2022) note that multiple changes in brain structure and function occur during adolescence. This observation has direct implications for the question of cognitive offloading: if executive functions such as planning, inhibitory control, working memory, and decision-making are still maturing during adolescence, the early delegation of these functions to AI systems may interfere with the maturation process itself.

The impacts of generative AI must be understood within a continuous trajectory of cognitive externalization that began with simple search engines. The so-called "Google effect" (Gong and Yang, 2024) turned the preference for searching for information online over memorizing it into a trend, particularly among those with a smaller prior knowledge base and among young people.

This finding anticipated what is now observed with generative AI: the most vulnerable groups are precisely those who most depend on mental exercise to build

their capacities. While internet search systems changed the way people use memory, generative AI tools are serving as substitutes for the very capacity to think.

As explained by Lent (2019), in order to acquire complex cultural competencies, the child's brain needs to reconfigure and repurpose already established neural pathways, directing them toward new functions. The process of literacy acquisition, for example, mobilizes neuroplasticity to occupy regions of the visual cortex in order to process written vocabulary. Analogously, the in-depth study of mathematics appropriates areas linked to the elementary perception of quantities in order to structure advanced logical reasoning. In sum, learning displaces and modulates neural networks in accordance with the specific demands of the received stimulus.

Considering this learning process, it can be seen that cognitive offloading through the use of generative AI may act as a suppressor of this essential environmental training. If the formation of complex neural networks depends on the child's active effort to occupy and reorganize the cortex through educational challenge, the systematic delegation of writing and reasoning to AI deprives the brain of the stimuli necessary for neural recycling.

Consequently, the absence of this cortical modulation represents not merely a temporary performance drop, but a structural interruption in the maturation of cognitive pathways, reinforcing the characterization of this practice as a violation of the full neurological development of children and adolescents.

4. Cognitive freedom as a neuroright: legal dimensions and proposals for normative protection

Having outlined this conceptual landscape of cognitive offloading and the risks involved in regular generative AI use in the learning and cognitive development of children and adolescents, it is necessary to explore a fundamental but still underexamined aspect: the challenges and questions related to the protection of the neurorights of these young individuals in the technological environment.

The emergence of neurorights as a specific category of legal protection represents a necessary response to the challenges posed by the intersection of neuroscience and digital technologies.

As Ana Maria D'Ávila Lopes notes regarding neurorights, "this is a complex subject with clearly innovative contours, whose questions may not find answers in the traditional theory of human rights, which is clearly ontological in character, thereby requiring the formulation of new rights" (Lopes, 2022).

Ienca and Andorno (2017) proposed four new human rights: the right to cognitive freedom, the right to mental privacy, the right to mental integrity, and the right to psychological continuity. Yuste *et al* (2017), representing the *Morningside Group*, published an article on the challenges of Neuroscience in the domains of privacy, identity, access to technologies, and algorithmic biases, highlighting to the international community the ethical priorities for neurotechnologies.

Ienca (2021), in a review article, traced the concepts of neurorights from the earliest formulations on freedom of thought, dating back to Ashoka in the 3rd century BCE, to current debates. The author notes that Boire (2001) and Sententia (2004)

were pioneers in the use of the term "cognitive freedom," defined as the right to mental self-determination.

This historical recovery is relevant because it demonstrates that the protection of the individual's mental sphere is not a concern that arose solely with the advancement of neurotechnologies, but stems from a dimension of human freedom recognized for centuries, one that acquires urgency in the face of the massive advent of new technologies.

Based on the systematization by Ligthart, Ienca *et al.* (2022), cognitive freedom is understood as the guarantee that the individual may cultivate and apply their mental faculties free from any external interference. This conceptualization, though concise, encompasses numerous dimensions. First, there is a negative dimension: protection against unconsented interference with the individual's mental processes. Second, a positive dimension: the right to fully develop the cognitive capacities the individual is potentially capable of. And third, a self-determination dimension: the right to decide autonomously how to exercise one's own mental capacity.

The neurorights literature has concentrated predominantly on the negative dimension, that is, protection against neural manipulation and unauthorized access to mental states. However, the positive dimension, which consists of the right to the full development of cognitive capacities, is equally fundamental and acquires special relevance in the protection of the rights of children and adolescents. A child whose cognitive development is undermined by the regular delegation of mental functions to AI systems has their cognitive freedom violated not because someone accessed their thoughts or neural data, but because the very conditions for the development of autonomous thought have been structurally compromised.

In proposing a governance framework for brain data, Ienca et al. (2022) highlight that such data represents the most direct representations of mental states, and that its uses are rapidly expanding into consumer devices and educational environments. Consequently, the protection of neural data is an essential component of the protection of cognitive freedom. And when it comes to children and adolescents, individuals whose neurodevelopmental trajectories are subject to irreversible alterations, this protection must be even more robust.

A fundamental pillar for ensuring comprehensive protection of the child population is the establishment of specific safeguards for the protection of neuropsychological development. According to the Committee on the Rights of the Child (UN, 2021), in General Comment No. 25 on the Rights of Children in Relation to the Digital Environment, States must ensure that the digital environment is compatible with the best interests of the child, which requires a review, adoption, and updating of national legislation in conformity with international human rights regulations. Such adaptation would need to include child rights impact assessments in legislative, budgetary, and administrative decisions related to the digital environment.

Also in accordance with the Committee on the Rights of the Child, States must ensure that the mandates of national human rights institutions, as well as other appropriate independent institutions, protect the rights of children in the digital environment, with the capacity to receive, investigate, and address complaints.

The development of media literacy skills and digital education must also be integrated into this protective framework. According to the aforementioned UN document, digital literacy must be taught in schools as part of the core curriculum, from early childhood education through secondary school. And in this educational process, it is necessary to include the development of skills to empower children and adolescents to handle digital tools safely and to engage in critical understanding of generative AI use.

It is therefore established that generative AI, by operating as a systematic cognitive offloading mechanism during critical periods of neurological development, interferes with the formation of autonomous cognitive capacities in children and adolescents, thereby constituting a violation of the right to cognitive freedom.

Metacognitive impairment prevents children or adolescents from perceiving their own loss, thereby eliminating the necessary condition for an autonomous decision about when to offload and when to invest their own effort. What distinguishes this process from a mere individual choice to use technology is its structural and asymmetric nature.

Children and adolescents are not in a position to give informed consent to the risks of early cognitive offloading, as they lack the neurological maturity to evaluate long-term consequences, do not possess the metacognition necessary to perceive the effects of ongoing cognitive atrophy, and are embedded in educational and family systems that frequently permit or even encourage the unrestricted use of these tools.

The violation of the cognitive freedom of children and adolescents through cognitive offloading with generative AI is not the isolated result of the intentional action of an identifiable agent. In fact, there is a convergence of structural factors that operates as a systemic violation of rights.

The social actors participating in this violation include: companies that develop and market generative AI systems without specific safeguards for minors; educational institutions that adopt these tools without adequate pedagogical mediation; the families of minors who allow unrestricted access without guidance; and the State, which has not established sufficient regulatory frameworks for protection.

Given the multiple agents responsible for the violation of children's right to cognitive freedom, effective protection in the era of generative AI requires action at multiple normative levels.

Comprehensive Protection of children encompasses the right to the full development of the child and adolescent and must be promoted and encouraged by all. In the face of the negative potential of AI-based technologies, especially for those who do not yet possess full mental discernment regarding the use of such tools, it becomes clear that the current Brazilian legal framework based on the CF/88, MCI, LGPD, and ECA is insufficient to protect children and adolescents from the potential risks, many of which are still unknown to the general public (Cruz and Pereira Junior, 2025).

It is therefore proposed that cognitive freedom be explicitly recognized as an autonomous fundamental right, derived from the dignity of the human person and the right to the free development of one's personality. This recognition finds support in both the international doctrine of neurorights and the Brazilian system of

Comprehensive Protection, and could be operationalized by means of a constitutional amendment.

In the regulatory domain, Nikolopoulou (2025) emphasizes that the integration of AI must place the child as its central focus, ensuring respect for the natural phases of development, a structural balance between the human and the artificial, and adequate preparation of the teaching staff. According to the author, a protective regulatory framework aligned with these principles would require: (i) mandatory cognitive impact assessments for AI systems intended for educational use; (ii) prohibition of AI design that maximizes engagement at the expense of cognitive development; (iii) mandatory qualified pedagogical mediation in all use of generative AI by minors in school settings; (iv) age limits based on neuroscientific evidence; and (v) mechanisms for platform accountability for documented cognitive harm.

In the legislative domain, the adoption of the *Children's Rights by Design* (CRbD) standard is proposed, formulated by Henriques and Hartung (2021) from the Instituto Alana of Brazil. This normative standard, inspired by *Privacy by Design*, integrates children's rights into all phases of the design of AI systems that directly or indirectly impact children and adolescents. The authors propose that every AI system that affects children must consider the rights and interests of the child as the highest priority, so as to ensure that data-based business models do not exploit children in predatory ways, thereby protecting their dignity and cognitive freedom.

In Brazil, the Statute of the Child and Adolescent (ECA), by assigning to the State, the family, and society the duty to ensure the rights of the child and adolescent with absolute priority, already provides the normative basis for shared responsibility. In this context, responsibility would not be merely individual or familial, but structural and shared. As Henriques and Hartung (2021) emphasized, the entire society, not only parents, is responsible for prioritizing the rights of children and adolescents in the development and regulation of AI use.

Conclusion

By operating as a systematic cognitive offloading mechanism, generative AI compromises fundamental processes of childhood neurodevelopment, including the formation of long-term memory, independent critical thinking, metacognition, and epistemic autonomy.

The impacts of regular generative AI use are considered more severe in children and adolescents due to the elevated neuroplasticity and metacognitive immaturity that characterize critical periods of development, constituting a disproportionate risk that demands specific legal protection.

In the field of neurolaw, cognitive freedom, understood as the right to develop and exercise cognitive capacities without external interference, possesses a positive dimension. This dimension, which guarantees the right to the full development of mental capacities, is directly violated when AI-mediated cognitive offloading undermines the neurological formation of children during a critical phase.

The proposal is not to prohibit access to technological innovation, but to recognize that its unrestricted use, without pedagogical mediation in the daily routines of

young people still in formation, constitutes a violation of the most intimate sphere of the human person: the autonomous capacity to think.

The Brazilian legal system, despite having applicable instruments for the protection of cognitive freedom, lacks specific tools to effectively combat the risks of AI-mediated cognitive offloading. Proposals for protection at the constitutional, legislative, and regulatory levels were presented: recognition of cognitive freedom as an autonomous fundamental right; legislative incorporation of guidelines that integrate children's rights into all phases of AI system design; and administrative regulation of cognitive impact assessments for AI tools used by young people.

The urgency of the proposed measures is proportional to the speed at which generative AI is spreading into the family and educational environments of children and adolescents. It must be recognized that there are thousands of developing brains exposed, without protection, to cognitive offloading mechanisms whose long-term consequences have not been fully understood.

The protection of the cognitive freedom of children and adolescents is not merely a legal or technological matter, but a civilizational question, one concerning the preservation of minimum conditions so that future generations may develop the mental capacities to exercise their citizenship, creativity, and humanity in a full and autonomous manner.

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