NOVA SCHOOL OF LAW

DIOGO MIGUEL DE BRITO FONSECA

BRAIN-COMPUTER INTERFACES AND THE DECODING OF THOUGHTS AS PERSONAL DATA OF THE MIND

Dissertation to obtain a Master's Degree in Law, in the specialty of Business Law and Technology.

Supervisor:
Dr. Maria da Graça Canto Moniz, Professor of NOVA School of Law

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ANTI-PLAGIARISM STATEMENT

I hereby declare that the work presented is my own essay and that all the citations are correctly acknowledged. I am aware that the use of unacknowledged extraneous materials and sources constitutes a serious ethical and disciplinary offense.

Diogo Miguel de Brito Fonseca

CITATION, FOOTNOTE AND REFERENCE METHOD

In the crafting of this master's thesis, the decision to adhere to the Chicago Manual of Style, 17th edition for citations, footnotes, and references was made with careful consideration of the norms and demands of academic writing, especially within the realm of legal research. The Chicago Manual of Style is widely recognized and respected within the academic community, notably in the social sciences, making it a fitting choice for a work that seeks to contribute meaningfully to the field.

It's important to acknowledge that legal research can present unique challenges and requirements that might necessitate deviations from standard citation guidelines. In this thesis, any such deviations have been made with deliberate intent, ensuring that they align with the specific demands and nuances of legal research. These adaptations are not arbitrary but are thoughtfully considered to enhance the overall quality and integrity of the research presented.

DEDICATIONS

To my family core and close friends,

This journey, marked by countless hours of study, research, and reflection, would not have been possible without the unwavering support and love of those closest to me.

Mother, father, and brother the foundation and my fortress. Your belief in my dreams, even when they seemed distant and challenging, has been the fuel that kept me going. Your sacrifices, encouragement, and unconditional love have shaped not only this thesis but the person I have become. Thank you for being my first teachers, my most loyal supporters, and my lifelong cheerleaders.

To my closest friends, Francisco, Maria and Luís, your camaraderie, laughter, and insights have lightened my load and brightened my path. You've been listening to my hauntings in the form of thoughts that tried to sabotage the relevance of my thesis topic and the (in)ability to write it with little doctrinal and jurisprudential support, reinforcing my competence and confidence in my work with quality and perseverance. Your friendship has been a source of joy and strength, reminding me that the journey is just as important as the destination.

This thesis is not just a reflection of my efforts, but a testament to your enduring presence in my life. It is dedicated to all of you who have made this accomplishment possible. Thank you for being my inspiration, my motivation, and my support system. You are the unsung heroes of this journey, and I am eternally grateful.

Also, I want to make an honourable mention to my thesis supervisor, Professor Maria da Graça Canto Moniz whose expertise, patience, and insight have been instrumental in guiding me through this academic endeavour. Your support, especially during times of adversity, has been a beacon of light, providing direction and encouragement. Your constructive feedback has been key to my growth and success in this journey.

STATEMENT

I, Diogo Miguel de Brito Fonseca, hereby inform that the main part of this master's dissertation has a total amount of 192,929 characters. According to the Regulations of NOVA School of Law, the limit is 200,000, including footnotes and spaces.

LIST OF ACRONYMS AND ABBREVIATIONS

AI: Artificial Intelligence

ALS: Amyotrophic Lateral Sclerosis

BCI: Brain-Computer Interface

CJEU: Court of Justice of the European Union

CNS: Central Nervous System

DMN: Default Mode Network

DPD: Data Protection Directive

ECoG: Electrocorticography

EEG: Electroencephalography

EU: European Union

fMRI: Functional Magnetic Resonance Imaging

GDPR: General Data Protection Regulation

MEA: Micro-Electrode Array

RNN: Recurrent Neural Network

WP29: Article 29 Data Protection Working Party

RESUMO

A nossa dissertação de mestrado pretende explorar a interseção da neurotecnologia, especificamente as Interfaces Cérebro-Computador (ICC), com as leis de proteção de dados, centrando-se exclusivamente no Regulamento Geral de Proteção de Dados (RGPD). Pretendemos abordar as profundas implicações dos recentes avanços nas ICC, e a perceção social, mas também científica, de que esta tecnologia poderá vir a permitir a descodificação de pensamentos, não se tratando apenas de um mero processamento e interpretação de dados cerebrais, mas sim de Dados Mentais, atingindo o âmago da nossa esfera íntima e do nosso Ser. Também aprofundamos a natureza dos pensamentos enquanto dados pessoais, sob uma combinação da perspetiva neurocientífica e psicológica, considerando a sua origem na mente e não no cérebro com uma exploração de várias teorias filosóficas da mente, intrinsecamente ligadas ao domínio subjetivo abstrato da mente. Os pensamentos posiciona-os como Dados Mentais pessoais únicos, mas também com um elevado grau de sensibilidade, protegidos pelo RGPD de acordo com a expansão do artigo 9.º deste regulamento pela decisão do Tribunal Europeu C-184/20. A dissertação fornece uma análise abrangente dos desafios e oportunidades apresentadas pelas ICC no contexto da proteção dos dados pessoais dos seus utilizadores, salientando a necessidade de assumir um papel evolutivo dos sistemas jurídicos em resposta aos avanços neurotecnológicos, fornecendo um quadro fundamental para a compreensão da complexidade das ICC e da sua interação e interpretação dos dados, abrindo caminho para mais investigação e desenvolvimento de políticas neste domínio em constante metamorfose.

Palavras-chaves: Dados Mentais, Dados Pessoais, Interface Cérebro-Computador, Neurotecnologia, Pensamentos, Regulamento Geral sobre a Proteção de Dados.

ABSTRACT

Our master's thesis aims to explore the intersection of neurotechnology, specifically Brain-Computer Interfaces (BCI), with data protection laws, exclusively focusing on the General Data Protection Regulation (GDPR). It addresses the profound implications of recent advances in BCI, and the social, but also scientific, realisation that this technology could make it possible to decode thoughts, not just processing and interpreting brain data, but Mental Data, reaching the core of our intimate sphere and our Being. We also intend to investigate the nature of thoughts as personal data, under a combination of a neuroscientific and psychological perspective, considering their origin from the mind rather than the brain, with an exploration of various philosophical theories of mind, intrinsically linked to the mind's abstract subjective realm. Thoughts position them as unique personal Mental Data, but also with a high degree of sensitivity, protected by the GDPR according to the expansion of Article 9 of this regulation by the decision of the European Court C-184/20. The dissertation provides a comprehensive analysis of the challenges and opportunities presented by BCIs in the context of the protection of its users' personal data, emphasising the need to take on an evolutionary role in legal systems in response to neurotechnological advancements, providing a foundational framework for understanding the complexities of BCIs and their interaction with personal data, paving the way for further research and policy development in this constantly metamorphosing field.

Key Words: Brain-Computer Interfaces, General Data Protection Regulation, Mental Data, Neurotechnology, Personal Data, Thoughts.

"*But if thought corrupts language, language can also corrupt thought*."

George Orwell - 1949[1]

INTRODUCTION

Most of the media examples, from the movie *The Matrix*[2] to *Inception*[3] and the series *Black Mirror*[4], generally paint a dystopian future for Brain Interface Technologies. They tell us a story of thought manipulation or behavioural mind control, a loss of humanness through an over reliance on technology, the ability for others to peer into our thoughts and memories or other dangerous effects when we express it in devices connected directly to our brains.

Since 2013[5], billions of euros have been allocated towards studying the human brain in the European Union, the United States of America and even China. This focus can be determined by the 'natural progression of behavioral studies that aim to demystify the unknown mechanisms behind the interaction of billions of neurons that make up the human brain'.[6] As there are at least a billion people on the planet who have disabilities,[7] it becomes a relevant opportunity to improve the lives of these people through technology capable of pursuing the interest of public and private health, however expensive research in the neuronal area, like for example Alzheimer's disease research,[8] may be.

The increasing of extra-medical availability of neural data raises risks that include 're-identification, hacking, unauthorized reuse, asymmetric commodification, privacy sensitive data mining, digital surveillance, trading rights-for-services, co-optation for

[1] George Orwell (2021). Nineteen Eighty-Four. Penguin Classics.
[2] Chicago. Wachowski, Lana, and Lilly Wachowski. 1999. The Matrix. United States: Warner Bros.
[3] Chicago. Nolan, Christopher. 2010. Inception. United States: Warner Bros.
[4] "The History of You", Black Mirror, Brian Welsh, Jesse Armstrong, season 1 episode 3, december 2011.
[5] Sten Grillner et al., "Worldwide Initiatives to Advance Brain Research," Nature Neuroscience 19, no. 9 (August 26, 2016): 1118–22. Available at: https://www.nature.com/articles/nn.4371.
[6] "Neurotechnologies: Connecting Human Brains to Computers and Related Ethical Challenges (ATP) - Policy Briefs & Reports - EPTA Network," (May 2019). Available at: https://eptanetwork.org/database/policy-briefs-reports/1792-neurotechnologies-connecting-human-brains-to-computers-and-related-ethical-challenges-atp.
[7] World Health Organization, "World Report on Disability 2011, page 11. Available at: https://apps.who.int/iris/handle/10665/44575.
[8] Alzheimer's association, 'Alzheimer's Breakthrough Act', august 2012. Available at: https://act.alz.org/site/DocServer/2012_ABA_Fact_Sheet.pdf;jsessionid=00000000.app20005a?docID=1921&NONCE_TOKEN=275A51DABCD7F1949DACF9680ADD25D1.

non-benign purposes, and other misuse',[9] for ethics and for human rights that require governance.[10] Due to this issue, in the last decade, we can find many studies in the fields of neuroethics and neurolaw that gives importance to a normative analysis of the ethical-legal challenges regarding the rights, freedoms, entitlements, and associated obligations, that resulted in the discussion of the necessity of "neurorights", the fundamental normative rules for the protection and preservation of the human brain and mind'[11] on the use of neurotechnologies.

'Neurotechnologies are emerging technologies that establish a connection pathway to the human brain through which human neuronal activity can be recorded and/or altered'[12] and are already being used, among others, to map brain regions related to different neuronal functions, to provide an image of the brain, and to repair its specific damaged areas.[13] These 'innovations have been found to facilitate the communication between the brain'[14] and the machines, such as orthoses and prostheses that have proven to be efficient and effective for the treatment of Parkinson's, blindness and other diseases and limitations by interpreting data from brain activity.

Brain activity is the basis of cognitive, affective, and survival state, being relevant to the extent that in many countries, 'death is legally defined by irreversible cessation of brain activity'[15] or the brainstem functions.[16] The centrality of this notion to others like human identity, freedom of thought, autonomy, privacy, and human well-being means

[9] Silja Vöeneky et al., "Towards a Governance Framework for Brain Data," Neuroethics 15, no. 2 (June 3, 2022), https://doi.org/10.1007/s12152-022-09498-8.

[10] International Bioethics Committee, "Report of the International Bioethics Committee of UNESCO (IBC) on the Ethical Issues of Neurotechnology," December 2021, page 6. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000378724.

[11] Marcello Ienca, "On Neurorights," Frontiers in Human Neuroscience 15 (September 24, 2021), page 2. Available at: https://doi.org/10.3389/fnhum.2021.701258.

[12] Committee on Bioethics (DH-BIO) of the Council of Europe and Marcello Ienca, "Neurotechnologies and Human Rights Framework: Do We Need New Rights?," October 2021, page 6. Available at: https://rm.coe.int/report-final-en/1680a429f3.

[13] "Neurotechnology: Premises, Potential, and Problems," Routledge & CRC Press, n.d., page 2-3. Available at: https://www.routledge.com/Neurotechnology-Premises-Potential-and-Problems/Giordano/p/book/9781439825860.

[14] Raimundo Roberts, "Neurotechnologies: Connecting Human Brains to Computers and Related Ethical Challenges," Biblioteca Del Congreso Nacional De Chile / BCN, May 2019, available at: https://obtienearchivo.bcn.cl/obtienearchivo?id=repositorio/10221/28289/1/If01_Neurotechnologies_BCN_eng.pdf.

[15] Report of the International Bioethics Committee of UNESCO (n 9), page 4.

[16] As defined in the Portuguese legal framework in Law 141/99 of 28 August that establishes the principles upon which the verification of death is based.

that the ethical, legal and societal impact of recording and/or modulating brain activity through various devices and procedures is vitally important to consider.[17]

The neurotechnology that is revolutionizing 'our understanding of the brain and its interaction with technology'[18] is the Brain-Computer Interface (BCI). BCIs manifest themselves in a collaboration between the human brain and an electronic device that receives signals from the brain to command an external activity, more specifically, 'a system that measures central nervous system (CNS) activity and converts it into an artificial output (response) that replaces, restores, complements, or enhances the output of the natural CNS and thereby modifies the ongoing interactions between the CNS and its external or internal environment'.[19]

The current state of this technology, as well as all its potential and splendor, is mirrored in the pivotal scientific study "A high-performance speech neuroprosthesis" presented in this thesis, focusing on the use of microelectrode arrays[20] to read Electrocorticography (ECoG), considered an invasive Brain-Computer Interface, at least compared to methods like Electroencephalography (EEG), which measures electrical activity along the scalp, not requiring surgical intervention. The article demonstrates that BCIs are capable of interpreting and translating from neural activities providing profound insights into the capabilities of BCIs to decode neural signals related to speech into comprehensible language. The study's ability to translate neural activities, particularly those associated with speech, into language, highlights the potential of BCIs to access and interpret thoughts, on this case a specific subset of thoughts - those related to speech and communication – but the technology operates on the same basic principles: 'they record neural activity — usually electrical activity — associated with a function such as speech

[17] Report of the International Bioethics Committee of UNESCO (n 9), page 4.
[18] Neuroscience News, "Interfacing Minds and Machines: An Exploration of Neural Implants and Brain-Computer Interfaces," June 17, 2023. Available at: https://neurosciencenews.com/brain-computer-interfact-neural-implants-23492/.
[19] Jonathan R. Wolpaw et al., "Brain–Computer Interfaces for Communication and Control," Clinical Neurophysiology 113, no. 6 (June 1, 2002): 767–91. Available at: https://doi.org/10.1016/s1388-2457(02)00057-3 in Raimundo Roberts (n 13), page 2-3.
[20] 'The MEA system enables simultaneous extracellular recordings from multiple sites in the network in real time, increasing spatial resolution and thereby providing a robust measure of network activity' in Andrew F.M. Johnstone et al., "Microelectrode Arrays: A Physiologically Based Neurotoxicity Testing Platform for the 21st Century," NeuroToxicology 31, no. 4 (August 1, 2010): 331–50. Available at: https://doi.org/10.1016/j.neuro.2010.04.001.

or attention; interpret what that activity means; and use it to control an external device or simply provide it as information to the user'.[21]

Therefore, we see that this technology is not yet capable of delving into the intricacies of thoughts, but there is a social and scientific perception of the eventual possibility of this personal and individual data to be decoded in the future.

The possibility of decoding human cognitive processes made us able to filter brain/neural data and thus opening the gates to the possibility of accessing the origin of our Self. Recent reports of the Council of Europe[22] and UNESCO's International Bioethics Committee[23], showcase various concerns regarding the rapid advancement of neurotechnologies and the need to reflect on the legal and ethical problems that arise in their use, with great emphasis on the issues around the use of data produced from brain recordings. Brain or Neural data, containing unique information on the physiology, health, and mental states of an identified individual, relevant in the context of personal data protection and the General Data Protection Regulation[24], has become a 'precious commodity that goes far beyond the medical sector, such as affective computing, which aims to interpret, process, and simulate different human emotional states'.[25]

The examination of how data from Brain-Computer Interfaces is categorized under data protection laws becomes complex when considering that not all data revealing physiological conditions of the brain can be directly linked to sensitive data, in the provisions of article 9 of the GDPR. This complexity arises because the source of this data is the brain or the mental state of the data subject, which does not automatically imply sensitivity. According to the definition of article 4(1) of the GDPR, as in WP29 Guidelines[26], and the Court of Justice of the European Union, CJEU, cases Breyer[27] and

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[21] Liam Drew, "The Rise of Brain-Reading Technology: What You Need to Know," Nature 623, no. 7986 (November 8, 2023): 241–43, https://doi.org/10.1038/d41586-023-03423-6.
[22] Report commissioned by the Committee on Bioethics (DH-BIO) of the Council of Europe (n 11).
[23] Report of the International Bioethics Committee of UNESCO (n 9).
[24] Official Journal of the European Union, "REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation)," 2016, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679.
[25] "Should We Be Afraid of Neuroscience?," The UNESCO Courier, October 9, 2023, page 7, https://courier.unesco.org/en/articles/should-we-be-afraid-neuroscience.
[26] ARTICLE 29 DATA PROTECTION WORKING PARTY, "Opinion 05/2014 on Anonymisation Techniques," April 2014, https://ec.europa.eu/justice/article-29/documentation/opinion-recommendation/files/2014/wp216_en.pdf.
[27] JUDGMENT OF THE COURT (Second Chamber), "Patrick Breyer v Bundesrepublik Deutschland in Case C-582/14," October 2016, [30].

Nowak[28] data that is related to the 'human brain and mind are always personal data if they allow to single out the data subject at stake'[29]. There is also a discussion in the doctrine regarding the relationship between mental data and brain data[30][31] within the fact that 'not all brain data are mental data as brain data can be processed to infer not only mental states but also basic brain anatomy and physiology, without disclosing mental states and processes'.[32]

However, when considering the content, context, and purpose of data processing,[33] it's possible that these types of data might reveal information related to the sensitive categories defined in Article 9(1) of the GDPR. This creates a conceptual and normative gap,[34] as authors have discussed regarding the protection gap in all mental data and the

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https://curia.europa.eu/juris/document/document.jsf;jsessionid=C46DB40CAC700B9AE3435EF04893B20C?text=&docid=184668&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=1228188

[28] Judgment of the Court (Second Chamber), "Peter Nowak v Data Protection Commissioner in Case C-434/16," December 2017, https://curia.europa.eu/juris/document/document.jsf?text=&docid=198059&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=1229492.

[29] Frederik J. Zuiderveen Borgesius, "Singling out People without Knowing Their Names – Behavioural Targeting, Pseudonymous Data, and the New Data Protection Regulation," Computer Law & Security Review 32, no. 2 (April 1, 2016): page 32, https://doi.org/10.1016/j.clsr.2015.12.013 in Marcello Ienca and Gianclaudio Malgieri, "Mental Data Protection and the GDPR," Social Science Research Network, January 1, 2021, page 8, https://doi.org/10.2139/ssrn.3840403.

[30] Authors that argue that neural data have a direct causal link with mental processes: Marcello Ienca, Pim Haselager, and Ezekiel J. Emanuel, "Brain Leaks and Consumer Neurotechnology," Nature Biotechnology 36, no. 9 (October 1, 2018): 805–10, https://doi.org/10.1038/nbt.4240; Marcello Ienca and Roberto Andorno, "Towards New Human Rights in the Age of Neuroscience and Neurotechnology," Life Sciences, Society and Policy 13, no. 1 (April 26, 2017), https://doi.org/10.1186/s40504-017-0050-1; Marcello Ienca and Karolina Ignatiadis, "Artificial Intelligence in Clinical Neuroscience: Methodological and Ethical Challenges," Ajob Neuroscience 11, no. 2 (March 31, 2020): 77–87, https://doi.org/10.1080/21507740.2020.1740352; Rafael Yuste et al., "Four Ethical Priorities for Neurotechnologies and AI," *Nature* 551, no. 7679 (November 1, 2017): 159–63, https://doi.org/10.1038/551159a.

[31] Example of an author that criticizes the division of neural data from brain data due to limited accuracy and reliability of the current available neurodevices: Anna Wexler, "Separating Neuroethics from Neurohype," Nature Biotechnology 37, no. 9 (August 9, 2019): 988–90, https://doi.org/10.1038/s41587-019-0230-z.

[32] Marcello Ienca and Gianclaudio Malgieri (n 28) page 7.

[33] Paul Quinn and Gianclaudio Malgieri, "The Difficulty of Defining Sensitive Data—The Concept of Sensitive Data in the EU Data Protection Framework," German Law Journal 22, no. 8 (December 1, 2021): 1583–1612, https://doi.org/10.1017/glj.2021.79; Karen McCullagh, "Data Sensitivity: Proposals for Resolving the Conundrum," Neliti, 2007, https://www.neliti.com/publications/28727/data-sensitivity-proposals-for-resolving-the-conundrum.

[34] Stephen Rainey et al., "Is the European Data Protection Regulation Sufficient to Deal with Emerging Data Concerns Relating to Neurotechnology?," Journal of Law and the Biosciences 7, no. 1 (January 1, 2020), https://doi.org/10.1093/jlb/lsaa051.

definition of ‘special categories of data’ being either purpose-based[35] or mostly contextual.[36]

The objective of this thesis is to critically analyze the intersection of Brain-Computer Interfaces, with ‘the most comprehensive and progressive piece of data protection legislation in the world, updated to deal with the implications of the digital age’,[37] the GDPR, addressing the complex challenges and implications arising from these technological advancements, and answering the pivotal question “Does the technological capability of BCIs inherently categorize thoughts, in their essence, as personal mental data under the GDPR?”

This question is crucial because thoughts, in our perspective, originate in the mind and not of the brain's physical processes. This distinction underscores the notion that thoughts are inherently a form of personal information, intrinsically connected to the abstract and subjective realm of the mind before being processed by the brain's neurobiological mechanisms. This perspective is vital for understanding the privacy and data protection implications of thoughts. It frames them not merely as byproducts of brain activity but as intimate reflections of the individual's inner mental landscape. Recognizing thoughts as primarily mental, rather than neurological, accentuates their sensitivity and the necessity of their protection within legal frameworks like the GDPR, something that is especially pertinent as technological advancements increasingly facilitate the externalization and quantification of these deeply personal cognitive processes, being able to expose the essence of all of us.

2. From Concept to Brain-Computer Interfaces

[35] Ibid, page 14, 16 and 17.
[36] Marcello Ienca and Gianclaudio Malgieri (n 28) states that ‘According to the contextual approach in the GDPR, all personal data should be assessed against the background of the context that determines their processing, as determined by several contextual factors (eg the specific interests of the controller, the potential recipients of the data, the aims for which the data are collected, the conditions of the processing and its possible consequences for the persons involved). In contrast, the purpose-based approach essentially looks at the intention of the data controller and asks whether the controller intends to draw conclusions from the processing of particular data that could be regarded as being sensitive in nature.’
[37] “Data Protection,” European Data Protection Supervisor, January 25, 2024, https://edps.europa.eu/data-protection_en.

2.1 Brain as the Centre of Consciousness

In the 16th century, the Belgian anatomist Andreas Vesalius published an article entitled "*De humani corporis fabrica libri septem*"[38] where he was able to be one of the first physicians to map the nervous system in a highly detailed way, arguing against the ventricles as the site of Galen's brain functions, a situation that we know today to be correct, as these are filled with cerebrospinal fluid that feeds the brain cells and cushions the brain against physical impact. Humanity had finally understood that the brain was the center of consciousness, however we didn't exactly possess the knowledge to study the inner workings of the brain, and the limitation of the technology at this time stymied progress toward a clearer understanding of the brain and how it worked for many years. Despite this challenge the functional areas of the brain became clearer in the year of 1666 when Thomas Willis released "Anatomy of the Brain"[39], an analysis that revolutionized our understanding of how sensory information was processed by the brain, and he laid the groundwork for our modern understanding of the nerves and how they communicate with the brain to provide information with the outside world.

2.1.1. Bioelectricity

By the XVIII century, we began to learn about a phenomenon known as bioelectricity, where cells within the body produce and respond to electrical signals, something that was observed by an Italian surgeon named Luigi Galvani in the 1780s that made possible the invention of the voltaic pile, a kind of battery that makes possible a constant source of current electricity.[40] He discovered that muscles moved in response to electricity when he observed a frog's leg twitch in response to electrical stimulation.[41] With the use of small metal-tipped devices and electricity, it was discovered that we could not only force muscles to contract, but also stimulate certain areas of the brain

[38] "Andreas Vesalius (1514–1564) | Embryo Project Encyclopedia," January 10, 2018, https://embryo.asu.edu/pages/andreas-vesalius-1514-1564.

[39] Walter Grand, "The Anatomy of the Brain, by Thomas Willis," Neurosurgery 45, no. 5 (November 1, 1999): 1234–37, https://doi.org/10.1097/00006123-199911000-00046.

[40] Bern Dibner, "Luigi Galvani | Italian Physicist & Discoverer of Animal Electricity," Encyclopedia Britannica, November 30, 2023, https://www.britannica.com/biography/Luigi-Galvani.

[41] "19th century physicians and scientists applied Galvani's model of the frog's muscular motion, which he considered the product of carefully balanced and imbalanced electrical currents, to new forms of medical therapy, which they called "Galvanism." Electrical medicine gave rise to new machines and new types of treatment", according to Whipple Museum of the History of Science, "Frogs and Animal Electricity". Available at: https://www.whipplemuseum.cam.ac.uk/explore-whipple-collections/frogs/frogs-and-animal-electricity.

causing them to activate. One such experiment in a human being was performed by researcher Roberts Barthalow in 1874. The subject whose consent was doubtful, was stimulated, unintentionally, into a seizure. Barthalow's work was not only ethically questionable but critiqued by researchers and physicians across the field[42], however he nonetheless had a relatively successful scientific career thereafter. This example has served as a cautionary tale in the field of neuroscience research and has encouraged the development of proper safeguards for neuroelectric stimulation.

Before we could make more significant progress in our understanding of how the brain works, humanity had to wait for technology to advance. We still didn't possess an imaging technique to observe the brain in due action. This all began to change with the advent of the radio in the early 1900s, where anatomists were taking advantage of microscopes and new staining methods which enabled neuroanatomists Camillo Golgi and Santiago Ramón y Cajal to receive the 1906 Nobel Prize for having identified in precise detail that neurons are different building blocks of the brain, developing 'the theory that the brain and spinal cord are made up of countless numbers of individual functional units, which his colleague Wilhelm von Waldeyer-Hartz later called neurons'.[43]

2.1.2. Electroencephalogram (EEG) and Electrocorticography (EcoG)

Over a period of almost 30 years of work, the neurologist and psychiatrist Hans Berger studied the brain and discovered something impressive. Through the use of small pieces of metal attached to wires, Berger was able to observe rhythms of electrical signals being emitted from the brain. These signals were then graphed on a piece of paper and laid the groundwork for the development of the modern Electroencephalogram (EEG). But perhaps more interesting than how Berger developed this technology was why he developed it. Berger's fascination with the workings of the human brain stemmed from his interest with what he described as "psychic phenomena". Though initially pursuing this interest through psychiatry, the author eventually developed a device in an attempt to capture psychic energy emitted from a person's brain, but what he found was that

[42] Lauren Julius Harris and Jason B. Almerigi, "Probing the Human Brain with Stimulating Electrodes: The Story of Roberts Bartholow's (1874) Experiment on Mary Rafferty," Brain and Cognition 70, no. 1 (June 1, 2009): 92–115, https://doi.org/10.1016/j.bandc.2009.01.008.

[43] "The Nobel Prize in Physiology or Medicine 1906," NobelPrize.org, n.d., https://www.nobelprize.org/prizes/medicine/1906/speedread/.

brainwaves change during a mental activity and during sleep.[44] Berger's device was later adapted and improved upon and regularly used as a standard for quantifying aspects of the brain noninvasively by researchers and doctors.

At the time of its creation however, researchers lacked methodological and procedural consistency. Even today, these failures of standardization are seen in other neurotechnology's derived from brain waves. Since EEG observes brain waves from outside the head, electrodes need to record through the electrically active head muscles, bone insulation and other protective layers around the brain. This great distance makes separating EEG from other biosignals very difficult to do repeatedly and accurately. To address this, and other issues, electrocorticography (ECoG) the recording of electrophysiological activity from electrodes placed directly on the exposed surface of a brain, most commonly during the surgical treatment of epilepsy[45], was developed in the 1937, by the neurosurgeon Wilder Penfield. Penfield demonstrated the mapping of motor, sensory, and language cortices by directly stimulating an open cortex in human patients[46] offering wider coverage of the cortical surface and the recording of field potentials at the neurone population level showcasing greater clinical viability than single neuron signals, a claim that has not been rigorously validated.[47]

2.1.3. Beginning of the neurotech era

In 1996, only around 15 years after the advent of *Hubel* and *Wiesel's* discoveries of the structure and function of the visual cortex, one of the first applications of implanted microelectrodes in the brain for visual prosthetics was demonstrated as feasible by E M Schmidt.[48] Since the early 1990s, *Miguel Nicolelis* has released a series of groundbreaking research papers which showcase the encoding of sensory information in primate brains. One of the most paradigm-shifting advancements Nicolelis made was his

[44] Rümeysa İnce, Saliha Seda Adanır, and Fatma Sevmez, "The Inventor of Electroencephalography (EEG): Hans Berger (1873–1941)," Childs Nervous System 37, no. 9 (March 5, 2020): 2723–24, https://doi.org/10.1007/s00381-020-04564-z.

[45] Gabriela Alcaráz and Pirjo Manninen, "Intraoperative Electrocorticography," Journal of Neuroanaesthesiology and Critical Care 04, no. 04 (February 1, 2017): S9–12, https://doi.org/10.4103/2348-0548.199942.

[46] Faisal R Jahangiri et al., "Mapping of the Motor Cortex," Cureus, September 25, 2020, https://doi.org/10.7759/cureus.10645.

[47] A Bolu Ajiboye and Robert F. Kirsch, "Invasive Brain–Computer Interfaces for Functional Restoration," in Elsevier eBooks, 2018, 379–91, https://doi.org/10.1016/b978-0-12-805353-9.00027-9.

[48] Edward M. Schmidt et al., "Feasibility of a Visual Prosthesis for the Blind Based on Intracortical Micro Stimulation of the Visual Cortex," Brain 119, no. 2 (January 1, 1996): 507–22, https://doi.org/10.1093/brain/119.2.507.

demonstrations of primates using their brain to control robotic arms over the internet, among others, while focusing on the development of a Brain-Computer Interface that motivates 'changes in the neural circuits that help the subject "feel as if the prostheses were part of the body'.[49]

As the age of the computers progressed to the XXI century and the internet became more widely accessible, computers began to enable high data throughput for neurotech like EEG. This led to the ability to control assistive technologies like robotic arms and legs, wheelchairs, and even computers themselves through the use of complex AI systems. Neurotechnologies have grown more powerful and accurate as the technologies behind computers have become better, faster, and more reliable.

2.2. Emergence of Brain-Computer Interfaces

The emergence of neurotechnology creates a unique opportunity to advance the human health sector and overcome natural biological limitations in ways never thought to be achieved. Neurotechnology includes 'technical and computational tools that measure and analyze chemical and electrical signals in the nervous system, be it the brain or nerves in the limbs; and technical tools that interact with the nervous system to change its activity'.[50] Since the late 1960s[51] a ramification of neurotechnology has been developed with the aim of not only reading brain activity, but also using it to create a direct communication channel with digital computers: the Brain-Computer Interface. BCIs, are a 'type of neurotechnology that aims to translate brain processes that underlie thought and action into desired outcomes by collecting the data related to neural activity by sensors or electrodes placed in the brain, on the brain, or over the surface of the scalp, transforming them into a signal and then converting this signal into a mechanical or electrical action'.[52]

[49] "Miguel Nicolelis 'The Future of Human Augmentation,'" Nokia Bell Labs, July 15, 2020, https://www.bell-labs.com/institute/blog/miguel-nicolelis-future-human-augmentation/#gref.
[50] Report of the International Bioethics Committee of UNESCO (n 9), page 5.
[51] Eberhard Fetz did an experiment in 1969 that connected a single neuron in a monkey's brain to an external device, a dial, so the animal could see. The monkey learned to make the neuron fire faster to move the dial intentionally, a study that is responsible for the creation of the Brain-Computer Interface, but not the machine itself.
[52] Report of the International Bioethics Committee of UNESCO (n 9), page 8-9.

It was through a paper published in 1973 by *Jacques Vidal* with the title "Toward Direct Brain-Computer Communication"[53] that we learn what this technological concept means. This project 'was meant to exploit the electrical activity arising from the brain to control a computer program'[54] considering that EEG waves contain usable concomitances of conscious and unconscious experiences that reflects relevant underlying neural events. Vidal knew that the feasibility of the communication concept was meant to be feasible only in the future, but concluded three relevant things that led the investigation further for other studies: (i) mental decisions and reactions can be probed that transcends behavior from the array of observable bioelectric signals and, in particular from the EEG potential fluctuations as measured on the human scalp; (ii) all meaningful EEG phenomena should be viewed as a complex structure of elementary wavelets that sequentially reflect individual cortical events and create a continuous flow of neuroelectric messages; (iii) operant conditioning procedures can increase the reliability and stability of these time signature and patterns. In the 1970s and early 1980s different studies tried to establish reliable communication channels between the brain activity of non-human animals and computer systems, but one in 1988 brought a lot of potential to improve the concrete idea of implementation of this interface.

The next relevant endeavor to establish direct communication between a computer and the brain of the human being was in 1988 with *Farwell* and *Donchin* in the study called "Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials".[55] This study aimed to develop and test a system that uses the P300[56] component linked to the event-related potential, ERP, raised in the decision-making process. The practical goal of this system was to aid and materialize verbal communication by individuals who cannot use a motor system for this purpose, using the 26 letters of the alphabet, along with various other symbols and commands that are displayed on a computer screen that serves as a keyboard or prosthetic device where the

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[53] Jacques J. Vidal, "Toward Direct Brain-Computer Communication," Annual Review of Biophysics and Bioengineering 2, no. 1 (June 1, 1973): 157–80, https://doi.org/10.1146/annurev.bb.02.060173.001105.

[54] Hakim Si-Mohammed et al., "Defining Brain-Computer Interfaces: A Human-Computer Interaction Perspective," ResearchGate, September 16, 2019, https://www.researchgate.net/publication/334094710_Defining_Brain-Computer_Interfaces_A_Human-Computer_Interaction_Perspective.

[55] Lawrence A. Farwell and Emanuel Donchin, "Talking off the Top of Your Head: Toward a Mental Prosthesis Utilizing Event-Related Brain Potentials," Electroencephalography and Clinical Neurophysiology 70, no. 6 (December 1, 1988): 510–23, https://doi.org/10.1016/0013-4694(88)90149-6.

[56] For more information related to the P300 wave See Terence W. Picton, "The P300 Wave of the Human Event-Related Potential," Journal of Clinical Neurophysiology 9, no. 4 (October 1, 1992): 456–79, https://doi.org/10.1097/00004691-199210000-00002.

subject focuses his attention on the characters he intends to transmit and the computer detects the chosen character online and in real time through rows and columns repeatedly flashing in a matrix. From the moment the character is detected, the P300 wave is triggered and detected by the computer. As ambitious as the study was, its final result in the use of this communication channel resulted in the almost ephemeral possibility of the subjects being able to communicate 2.3 characters per minute, as such, not practically a word per minute.

We may still be several decades away from being able to send someone else a thought, but despite the massive amounts of work left to do on the field, Neurotechnology is able to accomplish advanced tasks such as controlling robotic arms or even basic computer control. Considering the initiative of scientific vigor at the turn of the millennium, a new phase began which focused on the question of applying the knowledge acquired from the last century to restore motor independence for people affected by illness or injury with the first invasive interfaces applied in humans. In 1998 *Philip Kennedy* and *Roy Bakay*[57] made the first installation of 'a brain implant in a human being that produced signals of sufficient quality to simulate the patient's desired movements'.[58] The patient with Amyotrophic Lateral Sclerosis (ALS) was able to control the neural signals in an on / off fashion allowing her to learn to control a computer cursor through her own brain activity. 'The authors of this study envisioned that one day this type of BCI could control muscle stimulators and restore movement in paralyzed limbs'[59] but many other studies[60], in the meantime, used 'multi-electrode arrays to afford augmented communication and cursor control in persons living with movement impairment'[61] leading to 'cortically-

[57] Philip R. Kennedy and Roy A.E. Bakay, "Restoration of Neural Output from a Paralyzed Patient by a Direct Brain Connection," NeuroReport 9, no. 8 (June 1, 1998): 1707–11, https://doi.org/10.1097/00001756-199806010-00007.
[58] Report commissioned by the Committee on Bioethics (DH-BIO) of the Council of Europe (n 11), page 15.
[59] Santosh Chandrasekaran et al., "Historical Perspectives, Challenges, and Future Directions of Implantable Brain-Computer Interfaces for Sensorimotor Applications," Bioelectronic Medicine 7, no. 1 (September 22, 2021), https://doi.org/10.1186/s42234-021-00076-6.
[60] See "Decoding Neural Activity from an Intracortical Implant in Humans with Tetraplegia,'" IEEE Conference Publication | IEEE Xplore, March 1, 2009, https://ieeexplore.ieee.org/document/5090450; Leigh R. Hochberg et al., "Neuronal Ensemble Control of Prosthetic Devices by a Human with Tetraplegia," Nature 442, no. 7099 (July 1, 2006): 164–71, https://doi.org/10.1038/nature04970; Jennifer L. Collinger et al., "High-Performance Neuroprosthetic Control by an Individual with Tetraplegia," The Lancet 381, no. 9866 (February 1, 2013): 557–64, https://doi.org/10.1016/s0140-6736(12)61816-9.
[61] Chandrasekaran S, et al, (n 58).

controlled robotic arms and ultimately restoration of thought-mediated movement in paralyzed humans[62] as was previously imagined'.[63]

As our understanding of the brain improved, the scientists found more ways to use these devices to improve the quality of life for many people. We found that it was possible to improve rehabilitation for individuals with strokes, restore hearing loss, vision, and even allow for people who are paralyzed to walk again. As electronics continue to improve in complexity, we will undoubtedly make many breakthroughs and continue to help people in exciting new ways. There are many uses for Neurotechnology, whether it's for cognitive enhancement, brain research, alleviating symptoms of illness, modulating pain, or even improvements to existing technologies such as robotic prosthetics, we are very clearly just at the emergence of this amazing technology. Cognitive Enhancement[64], the ability to "upgrade" the brain, while previously only in the realm of science fiction appears to be close to science fact in the field of Neurotechnology.

2.3. Brain-Computer Interfaces state-of-the-art and Neurotech future

Many of neurotechnology devices are considered assistive technologies, including cochlear implants, robotic limps, devices that mitigate the motor limitations of Parkinson's disease, and as such are made available under the umbrella of safeguards of medical regulation, such as the Universal Declaration of Human Rights, the Nuremberg Code, the Declaration of Helsinki of the World Medical Association, and the International Ethical Guidelines for Biomedical Research Involving Human Subjects put forth by the Council for International Organization of Medical Sciences in collaboration with World's Health Organization'.[65] In the case of devices designed for non-medical purposes, there is currently no approved regulation defining ethical parameters for human enhancement issues and the use of data generated by brain activity.

[62] A Bolu Ajiboye et al., "Restoration of Reaching and Grasping Movements through Brain-Controlled Muscle Stimulation in a Person with Tetraplegia: A Proof-of-Concept Demonstration," The Lancet 389, no. 10081 (May 1, 2017): 1821–30, https://doi.org/10.1016/s0140-6736(17)30601-3.
[63] Chandrasekaran S, et al, (n 58).
[64] "Cognitive enhancement can be conceived as a benefit-seeking strategy used by healthy individuals to enhance cognitive abilities such as learning, memory, attention, or vigilance". Éric Racine, Sebastian Sattler, and Wren Boehlen, "Cognitive Enhancement: Unanswered Questions about Human Psychology and Social Behavior," Science and Engineering Ethics 27, no. 2 (March 23, 2021), https://doi.org/10.1007/s11948-021-00294-w.
[65] Raimundo Roberts (n 13).

As we have seen, the Brain-Computer Interface has shown promise for many different practical applications beyond theoretical digressions of those who dwell on them. But medical use cases are just the tip of the iceberg when it comes to taking full advantage of neurotechnology. There are already a large number of uses for BCI outside the medical field raging from the improvements of virtual reality systems to military applications[66] which over time has branched out into more and more niche applications to fulfil the different needs of the society.

Pursuant to the Brain/Neural Computer Interaction Horizon 2020 project, a European Commission project for the coordination of BCI research, the focuses of the application of this technology should be on the pillars of: *restore*, unlock the locked-in state of the patients suffering from such conditions; *replace*, through neuroprosthesis; *enhance*, the user experience in video games; *supplement*, add experiences like the use of augmented reality glasses; *improve*, such as upper limb rehabilitation after a stroke; and *research tool*, so we can decode the brain activity with real-time feedback, which all have been outlined as feasible and promising fields.[67]

Neuro-stimulation, the ability to directly send signals to the brain using electronics, could be used to improve performance in human perception, learning, memory, attention, and decision making. Several studies have laid the groundwork for humans to someday possess superhuman cognitive abilities, and neurotechnology could be the key to unlocking this. It's likely that in the future we will be able to treat cognitive disorders such as reading disabilities using neurotechnology, and some devices can already be used to treat dyslexia[68]. While wearing a device, participants were asked to read several sentences. The device was shown to improve reading speed significantly compared to when the participant was not wearing the device. For people who struggle with reading, this device could change the way they learn new information. These stimulating devices, neuroprosthesis, can help people struggling with dyslexia, but also can be used to improve the way that people learn.

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[66] Janggil Oh and Jong-Heon Kim, "Military Application Study of BCI Technology Using Brain Waves in Republic of Korea Army," 선진국방연구 5, no. 1 (April 30, 2022): 35–48, https://doi.org/10.37944/jams.v5i1.115.

[67] Clemens Brunner et al., "BNCI Horizon 2020: Towards a Roadmap for the BCI Community," Brain-Computer Interfaces 2, no. 1 (January 2, 2015): 1–10, https://doi.org/10.1080/2326263x.2015.1008956.

[68] "Review of Brain Computer Interface Application in Diagnosing Dyslexia," IEEE Conference Publication | IEEE Xplore, June 1, 2011, https://ieeexplore.ieee.org/document/5991843.

Amazingly, researchers were able to stimulate the hippocampus and allow for a transfer of memories between two animals.[69] But not only is there potential for these devices to improve cognitive abilities, it's also been found that it may be possible to directly influence human behaviour/humour using neurotechnology. Researchers found that stimulation of the prefrontal cortex, an area of the brain involved in evaluating risks and benefits resulted in participants exhibiting much riskier decision-making behaviours.[70] The ability to augment the way we think may just be the beginning for neurotechnology. It may be possible to develop ways to experience completely new senses with the use of BCIs.

Neurotechnology is primarily used within the research and medical fields at this time. The most prominent uses include seizure detection[71] and pain management.[72] By using a technology called Deep Brain Stimulation[73], people who suffer from Parkinson's disease can opt to undergo a surgery to be implanted with electrodes which stimulates the dopamine-producing areas of the brain. These devices help to mitigate the main symptom of Parkinson, uncontrollable muscle tremors. Prosthetic limbs are also a significant use case for neurotechnology. Many robotic prosthetics have been developed in recent years which can mimic the ability to grip materials using Electromyography[74]. Implanted electrodes can be placed on the brain's motor areas to provide a more advanced prosthetic. The complexity of these prosthetics' ranges from very simple "gripper" prosthetics to very complex fully developed articulating fingers controlled by the brain directly.

In November of 2022 a study[75] was shared that shows how real neurotechnology through BCI is contributing not only to the general welfare of society, but especially to

[69] Usha Lee McFarling and Stat, "Memory Transferred between Snails, Challenging Standard Theory of How the Brain Remembers," Scientific American, May 15, 2018, https://www.scientificamerican.com/article/memory-transferred-between-snails-challenging-standard-theory-of-how-the-brain-remembers/.
[70] Thomas Kroker et al., "Noninvasive Stimulation of the Ventromedial Prefrontal Cortex Modulates Rationality of Human Decision-Making," Scientific Reports 12, no. 1 (November 23, 2022), https://doi.org/10.1038/s41598-022-24526-6.
[71] Vaidehi D Naganur et al., "Automated Seizure Detection with Noninvasive Wearable Devices: A Systematic Review and Meta-analysis," Epilepsia 63, no. 8 (May 28, 2022): 1930–41, https://doi.org/10.1111/epi.17297.
[72] Lee E. Fisher and Scott F. Lempka, "Neurotechnology for Pain," Annual Review of Biomedical Engineering 25, no. 1 (June 8, 2023): 387–412, https://doi.org/10.1146/annurev-bioeng-111022-121637.
[73] A neuroscientific method that generates electrical impulses over localised brain areas to either disrupt or increase neural activity.
[74] Functional imaging tool that when placed on one's scalp can be used to track and record changes in the electrical activity of neurons.
[75] Luca Tonin et al., "Learning to Control a BMI-Driven Wheelchair for People with Severe Tetraplegia," iScience 25, no. 12 (December 1, 2022): 105418, https://doi.org/10.1016/j.isci.2022.105418.

members of society who tend to be marginalised or have special needs. The authors of the investigation found that 'a mind-controlled wheelchair can help a paralyzed person gain new mobility by translating users' brain signals into mechanical commands'[76] where the 'participants wore a skullcap that detected their brain activities through electroencephalography, which would be converted to mechanical commands for the wheelchairs via a brain-machine interface device'[77], consolidating at the end of the study, after a success rate between 95% and 98% of accuracy, that the device adapts to the individual brain and that it is necessary some neuroplastic reorganization of the cortex to fulfil the users control of the BCI.

Future computers are assumed to have emotional and perceptual capabilities, which could extend the use not only to assisting humans but also to making decisions,[78] which makes BCI, based on recent studies, a potential tool to investigate affective states with applications which enter the field of psychology[79] detecting positive and negative emotions induced by video stimulus,[80] but also other creative ways.

The integration of the artistic vein into BCI, Artistic BCI[81], has been explored since the late 1960s with *David Rosenboom* experimenting with ways to link brain functions with musical production, perception of musical forms and musical proprioception.[82] Virtual and augmented reality technologies together with BCI could offer immersive experiences and have many potential applications including arts and neurofeedback[83], but also in the gaming world where we have great strides in the possibility of several users

[76] "With Training, People in Mind-Controlled Wheelchairs Can Navigate Normal, Cluttered Spaces," ScienceDaily, November 22, 2022, https://www.sciencedaily.com/releases/2022/11/221118114824.htm.
[77] Ibid.
[78] "Group Overview ‹ Affective Computing – MIT Media Lab," MIT Media Lab, n.d., https://www.media.mit.edu/groups/affective-computing/overview/.
[79] "A Mutual Information Based Adaptive Windowing of Informative EEG for Emotion Recognition," IEEE Journals & Magazine | IEEE Xplore, n.d., https://ieeexplore.ieee.org/abstract/document/8367876.
[80] "An EEG-Based Brain Computer Interface for Emotion Recognition and Its Application in Patients with Disorder of Consciousness," IEEE Journals & Magazine | IEEE Xplore, n.d., https://ieeexplore.ieee.org/document/8651389.
[81] Marvin Andujar et al., "Artistic Brain-Computer Interfaces: The Expression and Stimulation of the User's Affective State," Brain-Computer Interfaces 2, no. 2–3 (April 3, 2015): 60–69, https://doi.org/10.1080/2326263x.2015.1104613.
[82] David Rosenboom, "Active Imaginative Listening a Neuromusical Critique," Frontiers in Neuroscience 8 (August 22, 2014), https://doi.org/10.3389/fnins.2014.00251.
[83] Felix Putze et al., "Editorial: Brain-Computer Interfaces and Augmented/Virtual Reality," Frontiers in Human Neuroscience 14 (May 12, 2020), https://doi.org/10.3389/fnhum.2020.00144.

participating in a collaborative game while being required to control the game environment from joint decision.[84]

Among the myriad of innovations in brain-computer interface technology, one of the most astonishing is Rao et al.'s[85] demonstration of telepathy-like communication through BCI and Computer-Brain Interface integration. This pioneering work suggests the potential for brain-to-brain interfaces, a concept still in the early stages of research.[86] Future explorations could include connecting human brains over the Internet of Things (IoT) network,[87] enhancing information and experience sharing. However, fully realizing this integration of BCI-IoT and other interfaces like mind-to-mind and mind-to-machine remains a formidable challenge, necessitating further research and adherence to ethical principles.

It is evident that BCIs represent a significant leap in neurotechnology, offering unprecedented opportunities for enhancing human capabilities, particularly for those with disabilities. The state-of-the-art of BCIs have shown potential in restoring lost functions and offering new modes of interaction between the brain and machines. However, this rapidly evolving field also faces considerable challenges, including ethical considerations, user-specific requirements, and the need for advanced technological solutions to ensure reliability and accessibility.

3. Brain-Computer Interfaces and the Decoding of Brain Signals

As we venture into a new chapter, our focus narrows to the groundbreaking technology of BCIs, which stands as a testament to the potential of brain and neural data to transform lives. Stephen Hawking's intriguing theory about uploading the human mind to a computer[88] opens a vast realm of possibilities in the context of Brain-Computer Interfaces. This philosophical proposition goes beyond the mere concept of consciousness, posing significant questions about the practicality and potential of BCIs

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[84] Yoones A. Sekhavat, "Battle of Minds: A New Interaction Approach in BCI Games through Competitive Reinforcement," Multimedia Tools and Applications 79, no. 5–6 (July 23, 2019): 3449–64, https://doi.org/10.1007/s11042-019-07963-w.

[85] Rajesh P. N. Rao et al., "A Direct Brain-to-Brain Interface in Humans," PLOS ONE 9, no. 11 (November 5, 2014): e111332, https://doi.org/10.1371/journal.pone.0111332.

[86] Elisabeth Hildt, "Multi-Person Brain-To-Brain Interfaces: Ethical Issues," Frontiers in Neuroscience 13 (November 5, 2019), https://doi.org/10.3389/fnins.2019.01177.

[87] "Brain-Computer Interface Control in a Virtual Reality Environment and Applications for the Internet of Things," IEEE Journals & Magazine | IEEE Xplore, 2018, https://ieeexplore.ieee.org/document/8302482.

[88] Jack Maidment, "Escenic," The Telegraph, n.d., https://www.telegraph.co.uk/news/science/10322521/Hawking-in-the-future-brains-could-be-separated-from-the-body.html.

in realizing such futuristic ideas. Key challenges include extracting and decoding memory signals from the brain for digital storage, a process that could revolutionize data processing, retrieval, and transmission, along with controlling external devices. Recent advancements in BCI technology have shown remarkable progress in translating brain signals into actionable data.[89] This has set a foundation for future explorations, where BCI might be utilized to capture and analyse human behaviours and traits for scientific research. However, this venture requires a stringent focus on ethical considerations, an area that needs more emphasis in the rapidly advancing field of BCI research.

Building on the potential of BCIs in memory uploading, one must ponder: if BCIs can decode memories, isn't it plausible they could also decode thoughts? This leads to the intriguing possibility and challenge of BCIs decoding thoughts. While current technology shows potential in interpreting brain signals for actions, decoding the intricate patterns of human thought is a significantly more complex task.

3.1. Depiction and capabilities of BCI Systems

‘BCI systems can be categorized by the way they use the brain: Passive BCI decode unintentional affective/cognitive states of the brain[90], while active BCI directly involve the user’s voluntary intention-induced brain activity’.[91] But the modern division of BCIs is according to the mode of signal acquisition, being divided into invasive, semi-invasive, and non-invasive. The invasive BCIs record the brain signalling by surgically implanting electrode arrays directly into the cortex or directly connected to the central nervous system[92], measuring the activity of a single neuron. Regarding the semi-invasive BCI, the electrodes are placed and found on the exposed surface of the brain, having as the main example the Electrocorticography signal that is taken from electrodes placed in the dura or arachnoid[93] part of the brain. Non-invasive BCIs have its sensors placed on the scalp to measure the electrical potentials produced by neuroimaging technologies such as Electroencephalography or even the magnetic field, Magnetoencephalography.[94]

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[89] Shaikh Nayeem Faisal et al., “Non-Invasive on-Skin Sensors for Brain Machine Interfaces with Epitaxial Graphene,” Journal of Neural Engineering 18, no. 6 (December 1, 2021): 066035, https://doi.org/10.1088/1741-2552/ac4085.
[90] Simanto Saha et al., “Progress in Brain Computer Interface: Challenges and Opportunities,” Frontiers in Systems Neuroscience 15 (February 25, 2021), page 2, https://doi.org/10.3389/fnsys.2021.578875.
[91] Ibid.
[92] Committee on Bioethics of the Council of Europe (n 11), page 16.
[93] Intro to brain computer inte
[94] “Intro to Brain Computer Interface,” NeurotechEDU, n.d., https://learn.neurotechedu.com/introtobci/.

The goal of a BCI is to detect and quantify the characteristics of brain signals that indicate the user's intentions and to translate those characteristics in real time into device commands that fulfil the user's intention. The interaction between the user's brain and the BCI system is made in a four-step cycle: input (signal acquisition), measurement and recording of brain activity (feature extraction), decoding and classification (feature translation) and the device output.[95] The input is the generation of specific brain activity, when the user is in certain cognitive state or performs a certain mental task, in response to a stimulus.[96] Brain activity is measured using a particular sensor modality, like the scalp or intracranial electrodes for electrophysiologic activity[97], being amplified to levels suitable for electronic processing, digitized and transmitted to the computer. After the broadcast the brain activity is measured, recorded, and analysed to distinguish pertinent signal characteristics during a cognitive process or the performance of a mental task, so we can differentiate noise,[98] random or unwanted electrical signals that distort the signals we are attempting to capture, and extraneous content from the user's intent. 'The recorded measurement can be implemented in different ways depending on the type of BCI in use'[99] being the most common way to extract the signal, a BCI time-triggered by EEG or ECoG response latencies and amplitudes or firing rates of individual cortical neurons. The characteristics of the neural data resulting from the brain signal obtained needs to be decoded to the feature translation algorithm so it can be usable by the BCI. The data is processed so we can have specific determined brain signals 'to increase the signal-to-noise ratio and to filter out the most relevant aspects of each signal for further processing'.[100] 'The translation algorithm should be dynamic to accommodate and adapt to spontaneous or learned changes in the signal features and to ensure that the user's possible range of feature values covers the full range of device control'[101], something that showcases the relevance of Artificial Intelligence and Machine Learning that provides

[95] Jerry J. Shih, Dean J. Krusienski, and Jonathan R. Wolpaw, "Brain-Computer Interfaces in Medicine," Mayo Clinic Proceedings 87, no. 3 (March 1, 2012): 268–79, https://doi.org/10.1016/j.mayocp.2011.12.008.
[96] Report commissioned by the Committee on Bioethics (DH-BIO) of the Council of Europe (n 11), page 16.
[97] Jerry J. Shih (n 94).
[98] Mohammad Javad Jafari et al., "The Effect of Noise Exposure on Cognitive Performance and Brain Activity Patterns," Open Access Macedonian Journal of Medical Sciences 7, no. 17 (August 30, 2019): 2924–31, https://doi.org/10.3889/oamjms.2019.742.
[99] Committee on Bioethics of the Council of Europe (n 11), page 16.
[100] Committee on Bioethics of the Council of Europe (n 11, page 17.
[101] Jerry J. Shih (n 94).

algorithms that are trained to decode the neural signals in an increasingly accurate manner. The final step represents 'the execution of the action initially intended or desired or deemed beneficial to the user through the control of the applications interfaced by the BCI'.[102] The algorithm commands operationalise the external device, providing functions depending on the goal of the application of the technology, supplying the feedback of the previous cycle, closing the control loop,[103] starting the next cycle for the following external action arise and only then do we have the data relatively clean to train the computers to recognize certain patterns to accomplish different tasks.

This is how many BCIs have accomplished incredible feats such as the full articulation of fingers in robotic prosthetics, with the knowledge of the frequency[104] at which brain waves are firing, generated from action potentials, and at what time the brainwaves fire[105], when the action potentials occurred. BCIs have been developed for people that have limited communication or motor capabilities. In the field of BCIs we must justify the potential benefit of the technology over the cost of installation, usability of the device, device maintenance, and the health of the user. If a technology requires brain surgery and a brain chip to be implanted, there is obviously a very high cost to not only undergoing the surgery but preventing complications such as scar tissue from forming.

On the other side, if we use a non-invasive BCI like EEG, the potential benefits aren't all that high. The many biological layers that muddy the signals for EEGs can distort and lower the usefulness of these devices for accomplishing real world tasks. Because of this, BCIs tend to be either semi-invasive or offer unique invasive procedures

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[102] Committee on Bioethics of the Council of Europe (n 11, page 17.

[103] James C. Wright et al., "A Review of Control Strategies in Closed-Loop Neuroprosthetic Systems," Frontiers in Neuroscience 10 (July 12, 2016), https://doi.org/10.3389/fnins.2016.00312.

[104] The frequency domain allows us to figure out at which rates certain groups of neurons may be firing within the brain and can generally help us understand how neurons within the brain are working together or against one another. When combined with the time domain, the frequency has helped scientists discover things like how the motor system within the brain works, and how signals propagate through certain areas of the brain to accomplish complex tasks such as vision or audition. For more information see Juan Bisquert, "A Frequency Domain Analysis of the Excitability and Bifurcations of the FitzHugh–Nagumo Neuron Model," The Journal of Physical Chemistry Letters 12, no. 45 (November 5, 2021): 11005–13, https://doi.org/10.1021/acs.jpclett.1c03406.

[105] The time series, data graphed in successive order over some period of time, may also be referred to as the Time Domain, useful in determining when an event has occurred in research and medical applications, but also useful for predicting when an event is about to take place, as certain patterns may emerge up to an event such an imagined motor task. See Juan Bisquert and Antonio Guerrero, "Dynamic Instability and Time Domain Response of a Model Halide Perovskite Memristor for Artificial Neurons," Journal of Physical Chemistry Letters 13, no. 17 (April 22, 2022): 3789–95, https://doi.org/10.1021/acs.jpclett.2c00790.

that mitigate any potential harm to the user, even if there are risks associated with these procedures. So, it makes sense that the primary users are those that struggle immensely due to their own physical limitations, and absolutely need to use a BCI to interact with the world or communicate. When it comes to the factors that influence the performance of BCI we must consider that a comfortable and convenient signal acquisition device is crucial, but also the system validation and dissemination and the reliability and potentiality of the BCI[106], all elements that are determined depending on the efficiency that a BCI can bring to the problem in question. For example, the invasive modality BCI is suitable for the locked-in patients, because the benefits outweigh the risks that are associated with the implantation, but it is not the case for the people that are neurologically intact because the risks that are associated with the surgery do not compensate for the inherent risks of medical intervention, due to the fact that in the first case we already have patients that have their neurological capacities affected, the surgery may be the only way to present an accurate solution for the concrete case, however, 'invasive recordings may enable the utilization of localized inner cortex activities and a better interpretation of surface recordings from a non-invasive modality'.[107]

For the sake of this thesis, we are focusing on the advancement of a non-Invasive type of BCI research study, but we will see that the conclusions are transversal to the technology as a whole.

3.2. From Neural Patterns to the Interpretation of Brain Signals

Having outlined the capabilities and functions of Brain-Computer Interfaces, we turn our focus to their practical applications, where these theoretical concepts are brought to life. The utility of BCIs extends far beyond the laboratory and into the fabric of everyday living, marking a paradigm shift in how we interact with technology. These interfaces, once a speculative fiction, are capable of offering revolutionary tools for communication and control that were previously inconceivable.

Brain-Computer Interfaces stand at the forefront of translating the brain's complex neural patterns into understandable thoughts and commands. This neurotechnological achievement, while groundbreaking, introduces significant legal considerations that pivot on the accuracy and interpretation of cognitive processes. BCIs decipher the brain's neural

[106] Jerry J. Shih (n 94).
[107] Simanto Saha, et al, (n 89), page 2.

lexicon—a sophisticated language of bioelectrical activity—into digital signals that machines can comprehend and act upon. This capability is not merely a technological marvel; it is a legal watershed moment where once abstract and private thoughts are transformed into observable, recordable data.

The accuracy of these interpretative technologies within BCIs is improving, promising greater precision in mapping neural signals to digital outputs. Such exactitude is crucial, especially when BCIs are employed as assistive communication devices for those with speech or motor impairments.

The implications of these applications are profound, not only in terms of technological advancement but also in their societal impact. BCIs represent a convergence of innovation and inclusivity, a bridge between human intention and digital execution.

It is within this context that we introduce a pivotal case study - a research endeavour that has successfully harnessed BCI technology to interpret and translate brain signals into language, contrary to the relatively low accuracies obtained in past studies.[108] This case study is not just a testament to the capabilities of BCIs but also a benchmark for examining the legal considerations surrounding the possible use of thoughts as data.

3.3. From Brain to Speech: Decoding of Neural Activity

The groundbreaking study titled "A high-performance speech neuroprosthesis"[109] revolves around a participant with amyotrophic lateral sclerosis utilizing a BCI that decodes neural activity related to attempted speech. The key components of its design include intracortical microelectrode arrays for neural signal recording, sophisticated decoding algorithms, and an effective interface for real-time communication.

Central to this design are the intracortical microelectrode arrays implanted within the participant's brain. These arrays are crucial for capturing spiking activities of neurons in regions linked to speech production. The high-resolution data obtained from these arrays enable detailed and precise recording of neural patterns, forming the backbone of

[108] Xiaokun Pei et al., "Decoding Vowels and Consonants in Spoken and Imagined Words Using Electrocorticographic Signals in Humans," Journal of Neural Engineering 8, no. 4 (July 13, 2011): 046028, https://doi.org/10.1088/1741-2560/8/4/046028; Emily M. Mugler et al., "Direct Classification of All American English Phonemes Using Signals from Functional Speech Motor Cortex," Journal of Neural Engineering 11, no. 3 (May 19, 2014): 035015, https://doi.org/10.1088/1741-2560/11/3/035015.

[109] Francis R. Willett et al., "A High-Performance Speech Neuroprosthesis," Nature 620, no. 7976 (August 23, 2023): 1031–36, https://doi.org/10.1038/s41586-023-06377-x.

the neuroprosthesis functionality. The decoding process of neural activity is a standout aspect of the neuroprosthesis. It employs a recurrent neural network (RNN) decoder that calculates the likelihood of each phoneme, the smallest unit of sound in speech,[110] being spoken at sequential time intervals. This phoneme prediction is intricately combined with a language model. The language model, based on the statistical properties of the English language, helps in accurately inferring the most probable sequence of words from the decoded phoneme probabilities. This integration is key to translating neural signals into coherent speech or text.

The BCI includes a real-time communication interface that converts the decoded neural signals into text. This feature allows the participant, who is unable to speak due to her condition to communicate effectively. The words decoded from the participant's neural data are displayed on a screen,[111] enabling a form of conversation, and providing immediate visual feedback. The machine system leverages high-density electrocorticography, coupled with advanced deep learning models, to interpret neural signals. The participant, profoundly affected by ALS, was engaged in attempts to articulate sentences silently. The BCI system, interpreting these attempts, translated the neural signals into both textual and synthesized speech forms.

The decoding process in this study is a sophisticated application of neural engineering and machine learning. At the heart of this process is a five-layer recurrent neural network[112] (RNN) decoder,[113] designed to interpret neural signals associated with speech attempts. This RNN operates by predicting the probability of each phoneme, or sound unit, being spoken at specific time intervals. Every 80 milliseconds[114], the decoder updates its prediction, providing a dynamic and continuous interpretation of the neural data. These phoneme probabilities are then intricately merged with a language model. This model utilizes the statistical characteristics of the English language to deduce the most likely sequence of words that corresponds to the neural signals. This integration is crucial, as it not only decodes the raw neural data into phonemes but also contextualizes these phonemes within the framework of coherent and grammatically accurate language.

[110] The Editors of Encyclopaedia Britannica, "Phoneme | Speech Sounds, Phonetics, Phonology," Encyclopedia Britannica, November 29, 2023, https://www.britannica.com/topic/phoneme.
[111] Francis R. Willett et al. (n 108), page 1032.
[112] 'A recurrent neural network (RNN) is a type of artificial neural network which uses sequential data or time series data' in "What Are Recurrent Neural Networks? | IBM," n.d., https://www.ibm.com/topics/recurrent-neural-networks.
[113] Francis R. Willett et al. (n 108), page 1033.
[114] Ibid, page 1032.

The effectiveness of this decoding process lies in its ability to translate thought-induced neural patterns into intelligible speech outputs. The high level of accuracy in phoneme prediction and word sequence inference marks a significant advancement over previous speech BCIs. The decoder's proficiency in real-time processing enables the study's participant to communicate at a remarkable speed. The real-time visual feedback of decoded words on a screen further enhances the communication experience, bridging the gap between attempted speech and external expression. This cutting-edge decoding process thus not only exemplifies a technological triumph in speech neuroprosthetics but also promises a new era of communication aids for individuals with speech impairments.

The training of the RNN decoder in the study is a critical phase that ensures its accuracy and effectiveness in real-time speech decoding. This training involves a comprehensive process where the study's participant, referred to as T12, attempts to speak various sentences selected from the Switchboard corpus[115] of spoken English. During these sessions, T12's neural activity, while attempting to speak, is recorded to gather extensive data on the neural correlates of speech attempts. This data forms the training set for the RNN. The uniqueness of this training lies in its adaptive nature - each day's training data is combined with data from previous sessions, accounting for variations in neural activity across different days. This approach allows for the continuous refinement and improvement of the RNN's decoding capabilities. Additionally, the researchers employ custom machine learning methods tailored to optimize performance on the limited but high-resolution neural data. These methods include unique input layers for each day to address across-day changes in neural patterns and rolling feature adaptation for within-day fluctuations.

Over time, the RNN's training becomes increasingly robust, culminating in a dataset consisting of thousands of sentences. This extensive training ensures that the RNN can accurately interpret neural signals corresponding to a wide range of spoken sentences. By the final stages of the study, the trained RNN demonstrates remarkable proficiency in decoding speech from neural data in real-time, even for sentences it was never exposed to during training. The evolution of the RNN's capabilities, from initial training to its final high-performance state, is a testament to the potential of machine learning in enhancing neuroprosthetic technologies. The careful and systematic approach to data collection in this study was pivotal in capturing the intricate details of neural activity associated with

[115] "SWITCHBOARD: Telephone Speech Corpus for Research and Development," IEEE Conference Publication | IEEE Xplore, 1992, https://ieeexplore.ieee.org/document/225858/.

speech attempts. The richness and diversity of the collected data played a crucial role in the success of the neuroprosthesis, demonstrating the feasibility of restoring speech capabilities through advanced neurotechnology.

3.3.1. Conclusions of the Scientific Study

Remarkably, the study's BCI system achieved a substantially low word error rate, 9.1% for a 50-word vocabulary and 23.8% for a 125,000-word vocabulary,[116] a significant advance in accuracy for small vocabularies.[117] This performance was complemented by a decoding speed of 62 words per minute. The study also highlighted the persistence of detailed articulatory representations of phonemes in the participant's brain, even years after the onset of paralysis, suggesting a resilient neural encoding mechanism for speech.

The speed of communication achieved through the neuroprosthesis was another remarkable aspect, significantly enhancing the practical utility of the system. The participant was able to communicate at an average pace of 62 words per minute, more than tripling the speed of previous state-of-the-art BCIs. This rate begins to approach the speed of natural conversation, which typically averages around 160 words per minute. Such an achievement in communication speed not only enhances the user experience but also brings the technology closer to practical, everyday usability. Additionally, the study provided valuable insights into the neural code for speech. It highlighted that accurate decoding is possible from only a small region of the cortex thanks to spatially intermixed tuning to speech articulators.

Moreover, the research showed that a detailed articulatory representation of phonemes persists years after paralysis.[118] These insights into the neural coding of speech articulation are encouraging for the development of future speech BCIs, as they suggest that even with limited cortical sampling areas, robust speech decoding can be achieved. The combination of high-speed communication and deep neural code understanding paves the way for more advanced and user-friendly neuroprosthetic solutions in the future.

Perhaps the most striking implication of this study is its potential relevance to the interpretation of thoughts. The ability of the BCI system to decode neural signals

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[116] Francis R. Willett et al. (n 108), page 1033.
[117] David A. Moses et al., "Neuroprosthesis for Decoding Speech in a Paralyzed Person with Anarthria," The New England Journal of Medicine 385, no. 3 (July 15, 2021): 217–27, https://doi.org/10.1056/nejmoa2027540.
[118] Francis R. Willett et al. (n 108), page 1035.

associated with attempted speech into coherent language offers a glimpse into the possibilities of accessing and interpreting internal speech - a proxy for thought. This finding bridges the gap between the neural activity and complex cognitive processes, indicating that internal speech, an integral part of human thought, could be externalized and understood through advanced BCI systems.

3.3.2. Catalysing Communication Breakthroughs: The Transformative Potential of Advanced Speech BCI

The advancements demonstrated in the "A High-Performance Speech Neuroprosthesis" study opens significant possibilities for enhancing communication capabilities for individuals with paralysis, particularly those who have lost the ability to speak. The neuroprosthesis ability to decode attempted speech into text or sound in real time offers a new avenue for these individuals to engage in conversations and express themselves. This technology could potentially transform the lives of people with conditions like ALS or those who have suffered from strokes, providing them with a tool to communicate effectively despite their physical limitations. The prospect of restoring such a fundamental aspect of human interaction – speech – represents not just a technological breakthrough but a substantial improvement in the quality of life for those affected by severe speech impairments.

What has been shown signifies a leap forward in the field of neurotechnology, particularly in the development of BCIs. The demonstrated capability of decoding neural signals with high accuracy and speed paves the way for further advancements in neuroprosthetic devices. Clinically, this technology has the potential to be developed into a viable solution for speech restoration but also refined and adapted for broader clinical applications, providing a new therapeutic option for patients with speech and motor impairments. As the technology evolves, it could also lead to advancements in treating a wider range of neurological conditions, where communication difficulties are a primary concern.

The insights gained into the neural coding of speech and the effectiveness of the RNN decoder in processing complex neural data are invaluable for the future design of more sophisticated BCIs. Researchers can build upon these findings to enhance the accuracy, speed, and usability of neuroprosthetic devices. Future research might focus on expanding the vocabulary size, reducing the word error rate further, and simplifying the training process for the neural decoder. Additionally, the exploration of similar technologies for other forms of neural decoding, such as motor activity[119] or sensory inputs,[120] could be a significant area of development.

So, we are able to realise and conclude that Brain-Computer Interfaces primarily process neural signals from their users, which are the electrical and chemical activities occurring within the brain. These signals are captured through various methods such as electroencephalography or intracortical microelectrode arrays, depending on the complexity and purpose of the BCI. The fundamental principle of BCI operation is to interpret these neural signals, which are manifestations of brain activity, and convert them into commands or outputs that can interact with external devices or software. These neural signals are typically associated with specific brain functions or tasks, such as motor commands in movement-related areas or neural activity patterns related to sensory processing. The significant challenge for BCIs is to accurately decode these signals and 'behavior accurately from time-varying neural oscillations',[121] which involves complex algorithms and machine learning techniques to distinguish between different patterns of brain activity and translate them into meaningful actions or communications, as showcased with a high degree of success on the scientific study above.

The exploration of BCIs in the scientific study, particularly their ability to decode speech from neural activity, brings us to the cusp of a significant query: what exactly are thoughts? This question is not just a philosophical or neuroscientific one, but also a legal and ethical conundrum, especially as we begin to navigate the realms where any thought might be considered personal data. If thoughts are deemed personal data, they warrant the same level of protection as other personal identifiers, necessitating a re-evaluation and potential expansion of existing data protection laws. Therefore, understanding whether and how thoughts fit into the paradigm of personal data is not only a step towards safeguarding individual privacy but also a necessary discourse in guiding ethical technological development.

As we move on to the next chapter, we delve into the fundamental issue of determining the concept of thought, a reality that needs to be clarified so that we can

[119] Julie G. Hensler, "Serotonin," in Elsevier eBooks, 2012, 300–322, https://doi.org/10.1016/b978-0-12-374947-5.00015-8.

[120] Xiaowei Chen et al., "Therapeutic Effects of Sensory Input Training on Motor Function Rehabilitation after Stroke," Medicine 97, no. 48 (November 1, 2018): e13387, https://doi.org/10.1097/md.0000000000013387.

[121] Venkatesh Elango, "Sequence Learning for Brain Computer Interfaces," 2017, https://escholarship.org/uc/item/6gn763m3.

concretely realise whether these processes, rather than neural ones, are personal data deserving of legal protection.

4. Mind-Centric Origin of Thoughts

Thoughts, in a broader sense, encompass a wide range of cognitive processes, including conscious deliberation, subconscious mental activities, and emotional responses. In the context of BCIs, especially advanced ones like the speech decoder already presented, there is a movement towards interpreting neural signals that correlate with specific thought processes, such as the intention to speak or move. This involves not only capturing the raw brain/neural data, but also understanding the underlying intention or cognitive state represented by these signals. However, affirming these signals as thoughts in their entirety is a more nuanced matter. While BCIs are becoming increasingly sophisticated in interpreting certain types of brain activity that are closely related to thoughts, fully capturing the complexity and depth of human thought in its complete form is a challenge that remains at the frontier of neuroscience and neurotechnology research.

The study "A high-performance speech neuroprosthesis" primarily indicates that specific neural activity, when decoded through advanced BCI technology, can be translated into speech. There are also many different studies at the time of writing this thesis that provide with enough information that brain signals associated with speech are able to be recorded and engraved from specific articulatory motor areas in the brain.[122] 'When speech is imagined, vividly, but not spoken aloud, the same articulatory motor brain areas are activated to a lesser but detectable degree',[123] being an indicator of the sound that could be emanated, even in the absence of actual vocalization. This process demonstrates a significant relationship between neural signals and the thought processes involved in generating speech. However, it's crucial to understand that this does not universally apply to all thoughts or types of neural activity. The study's focus is on the neural representation of speech, a specific aspect of thought, showcasing the capacity of BCIs to interpret and translate these specific neural patterns, suggesting the possibility of

[122] Florent Bocquelet et al., "Real-Time Control of an Articulatory-Based Speech Synthesizer for Brain Computer Interfaces," PLOS Computational Biology 12, no. 11 (November 23, 2016): e1005119, https://doi.org/10.1371/journal.pcbi.1005119.
[123] Stephen Rainey et al. (n 33).

accessing and externalizing certain types of thoughts, particularly those related to speech and communication.

Thought is one of the most subjective, intriguing, and complex realities of the human being, to the extent that there is no consensus on how we can define it. There are authors who say that thought needs to contain language or symbolic representation,[124] which makes it a capacity that is exclusively ours, but there are also those who say that *flora* can be capable of thinking.[125] 'Altogether what we have so far are quite remarkable decoding of the input and output signals'[126] which means that we can't yet understand the abstract reality that lies between these signals and that manifests itself in thoughts. Nevertheless, it is necessary to conceptualize and define what thoughts really are, and not just a mere academic exercise but a pivotal journey into the very fabric of human cognition and its legal implications. By unravelling the concept of thought from both neuroscientific and psychological perspectives, we gain invaluable insights into how thoughts are formed in the mind and then processed and manifested in the human brain.

Since this is a perspective aspect of the consideration of the concept of thought, we will take the liberty of stating our arguments and views in a dogmatic sense.

4.1. The Neural Tapestry of Thoughts: A Cognitive Neuroscientific Perspective

Unravelling the aspects related to neural mechanisms underlying various thought processes remains a pivotal objective in the field of cognitive neuroscience.[127] From a neuroscientific viewpoint, thoughts are primarily understood as products of brain activity. This perspective delves into the realm of neurons, based on the neural theory proposed by Santiago Ramón y Cajal and Camilo Golgi already mentioned, and how their complex networks and interactions result in the formation of thoughts. When we think, there is a cascade of electrical and chemical activities in the brain – neural impulses travel through

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[124] Lera Boroditsky, "How Language Shapes the Way We Think," IRL @ UMSL, n.d., https://irl.umsl.edu/oer/13/.

[125] Monica Gagliano, "The Mind of Plants: Thinking the Unthinkable," Communicative & Integrative Biology 10, no. 2 (February 17, 2017): e1288333, https://doi.org/10.1080/19420889.2017.1288333.

[126] Sapien Labs, "Reading a Thought - Sapien Labs | Neuroscience | Human Brain Diversity Project," Sapien Labs | Neuroscience | Human Brain Diversity Project, August 29, 2022, https://sapienlabs.org/lab-talk/reading-a-thought/.

[127] Kalina Christoff et al., "Mind-Wandering as Spontaneous Thought: A Dynamic Framework," Nature Reviews Neuroscience 17, no. 11 (September 22, 2016): 718–31, https://doi.org/10.1038/nrn.2016.113.

synapses, facilitated by neurotransmitters.[128] Different patterns of these neural activities correspond to different types of thoughts. For example, contemplating a mathematical problem activates different neural circuits compared to recalling a memory or experiencing an emotion. Neuroscientists study these patterns using advanced imaging technologies like fMRI, ECoG and PET[129] (Positron Emission Tomography) scans, which allow them to observe which areas of the brain are active during various thought processes.

In understanding thoughts, neuroscientists also focus on the specific brain regions involved in different cognitive functions. The prefrontal cortex, for instance, plays a key role in higher-order cognitive functions like decision-making, problem-solving, and planning.[130] Meanwhile, areas like the hippocampus are crucial for memory formation and retrieval[131], a critical aspect of how we think and process information. Additionally, the interconnectivity between different brain regions is essential in forming coherent thoughts. This interconnectivity ensures that thoughts are not isolated events but are influenced by various cognitive processes and previous experiences.

The brain's ability to generate and process thoughts is a multifaceted phenomenon that extends beyond the realms of any single network or system, comprising (i) the necessity to understand the comparative neuroanatomy of different thought processes;[132] (ii) the interplay of neurochemistry in cognitive and emotional thinking;[133] (iii) the influence of the limbic system in integrating emotion with cognition;[134] (iv) conscious

[128] David M. Lovinger, "Communication Networks in the Brain: Neurons, Receptors, Neurotransmitters, and Alcohol," ResearchGate, January 1, 2008, https://www.researchgate.net/publication/236181567_Communication_networks_in_the_brain_Neurons_receptors_neurotransmitters_and_alcohol.

[129] Yen F. Tai and Paola Piccini, "Applications of Positron Emission Tomography (PET) in Neurology," Journal of Neurology, Neurosurgery, and Psychiatry 75, no. 5 (May 1, 2004): 669–76, https://doi.org/10.1136/jnnp.2003.028175.

[130] Shazia Veqar Siddiqui et al., "Neuropsychology of Prefrontal Cortex," Indian Journal of Psychiatry 50, no. 3 (January 1, 2008): 202, https://doi.org/10.4103/0019-5545.43634.

[131] Joel L. Voss et al., "A Closer Look at the Hippocampus and Memory," Trends in Cognitive Sciences 21, no. 8 (August 1, 2017): 577–88, https://doi.org/10.1016/j.tics.2017.05.008.

[132] Christopher G. Coutlee and Scott A. Huettel, "The Functional Neuroanatomy of Decision Making: Prefrontal Control of Thought and Action," Brain Research 1428 (January 1, 2012): 3–12, https://doi.org/10.1016/j.brainres.2011.05.053.

[133] Shanqiang Gu et al., "The Neural Mechanism Underlying Cognitive and Emotional Processes in Creativity," Frontiers in Psychology 9 (October 31, 2018), https://doi.org/10.3389/fpsyg.2018.01924.

[134] Marco Catani, Flavio Dell'Acqua, and Michel Thiebaut De Schotten, "A Revised Limbic System Model for Memory, Emotion and Behaviour," Neuroscience & Biobehavioral Reviews 37, no. 8 (September 1, 2013): 1724–37, https://doi.org/10.1016/j.neubiorev.2013.07.001.

and unconscious thoughts; (v) the role of neuroplasticity in cognitive development;[135] (vi) the impact of external stimuli on thought processes; and (vii) the Default Mode Network (DMN) on creative thinking. In order not to deviate from the purpose of this thesis, we will take a brief look at what has been determined by neuroscientific studies in these dimensions of thought.

The neuroanatomy of thought processes is a cornerstone in understanding the complexities of human cognition. The prefrontal cortex, central to executive functions, plays a pivotal role in decision-making, planning, and moderating social behaviour.[136] This region's intricate neural circuits facilitate higher-order cognitive functions,[137] underpinning our ability to think abstractly and plan. Meanwhile, the amygdala, crucial in emotional processing,[138] "colours" our thoughts with emotional hues, influencing everything from memory recall to decision-making under stress. The occipital lobes, tasked with visual processing, shape how we interpret visual information, influencing our visual imagination and perception.[139] Together, these regions exemplify the diverse neural underpinnings that contribute to the rich tapestry of human thought.

Neurochemistry adds another layer to the understanding of thought processes. Neurotransmitters like dopamine, serotonin, and norepinephrine orchestrate a complex symphony of brain activities. Dopamine, associated with reward and pleasure circuits,[140] influences motivation and goal-oriented thinking. Serotonin regulates mood and emotional well-being, affecting our outlook on life, anxiety levels, and overall emotional stability.[141] Norepinephrine, involved in arousal and alertness,[142] affects focus and

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[135] Joan Stiles, "Drawing Abilities in Williams Syndrome: A Case Study," Developmental Neuropsychology 18, no. 2 (October 1, 2000): 237–72, https://doi.org/10.1207/s15326942dn1802_5.

[136] Shintaro Funahashi, "Prefrontal Contribution to Decision-Making under Free-Choice Conditions," Frontiers in Neuroscience 11 (July 26, 2017), https://doi.org/10.3389/fnins.2017.00431.

[137] Melvin D. Levine, "DIFFERENCES IN LEARNING AND NEURODEVELOPMENTAL FUNCTION IN SCHOOL-AGE CHILDREN," in Elsevier eBooks, 2009, 535–46, https://doi.org/10.1016/b978-1-4160-3370-7.00055-9.

[138] Mark G. Baxter and Paula L. Croxson, "Facing the Role of the Amygdala in Emotional Information Processing," Proceedings of the National Academy of Sciences of the United States of America 109, no. 52 (December 14, 2012): 21180–81, https://doi.org/10.1073/pnas.1219167110.

[139] Amna Rehman, "Neuroanatomy, Occipital Lobe," StatPearls - NCBI Bookshelf, July 24, 2023, https://www.ncbi.nlm.nih.gov/books/NBK544320/.

[140] Robert W. Lewis et al., "The Brain's Reward System in Health and Disease," in Advances in Experimental Medicine and Biology, 2021, 57–69, https://doi.org/10.1007/978-3-030-81147-1_4.

[141] James McIntosh, "What Is Serotonin, and What Does It Do?," October 11, 2023, https://www.medicalnewstoday.com/articles/232248.

[142] Cleveland Clinic Medical Professional, "Norepinephrine (Noradrenaline)," Cleveland Clinic, n.d., https://my.clevelandclinic.org/health/articles/22610-norepinephrine-noradrenaline.

response to stimuli. The intricate balance and interactions of these chemicals are vital in maintaining cognitive health and emotional balance.

The limbic system, encompassing the amygdala and hippocampus, is central to the interplay between emotion and cognition. This system processes emotional responses, while also playing a pivotal role in memory formation[143] and retrieval, integrating emotional experiences with cognitive functions. The limbic system's functioning is crucial for a holistic understanding of how emotions and thoughts are intertwined, shaping our daily experiences and long-term memories.

Cognition is also a complex interplay between conscious and unconscious processes, each playing a distinct yet interconnected role in shaping our thoughts and behaviours. Conscious thoughts are the aspects of our cognition that we are directly aware of and can articulate, encompassing our rational thinking, deliberate decision-making, and focused attention, making us able to engage in active problem-solving and process information that we are directly attending to.[144] This mode of thought is akin to the spotlight of our awareness, illuminating specific aspects of our experience and allowing for a detailed examination and manipulation of ideas. In contrast, unconscious thoughts represent a vast, often uncharted area of the mind, encompassing processes and activities that occur beyond our conscious awareness, in different interrelated brain regions.[145] These thoughts include a range of elements such as automatic skills, implicit biases, deep-seated fears and desires, and habitual responses, subtly influencing our behaviour and attitudes without conscious recognition. The unconscious mind, a deep reservoir of feelings, urges, and memories, significantly shapes our beliefs and behaviours, even though these elements remain outside our direct awareness. While conscious thought allows for reflection and deliberate action, the unconscious mind is a wellspring of intuition, creativity, and deep-seated emotions.

Another crucial aspect in the neuroscientific understanding of thoughts is neural plasticity – 'the ability of the nervous system to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections after injuries,

[143] Amber Felton, "Limbic System: What to Know," WebMD, September 8, 2022, https://www.webmd.com/brain/limbic-system-what-to-know.
[144] Ana B. Chica and Paolo Bartolomeo, "Attentional Routes to Conscious Perception," Frontiers in Psychology 3 (January 1, 2012), https://doi.org/10.3389/fpsyg.2012.00001.
[145] Emily Sohn, "Decoding the Neuroscience of Consciousness," Nature 571, no. 7766 (July 1, 2019): S2–5, https://doi.org/10.1038/d41586-019-02207-1.

such as a stroke or traumatic brain injury'.[146] This plasticity is observed in how experiences and learning can alter neural connections, subsequently affecting our thought processes. For instance, learning a new language or adapting to a new environment requires the brain to form new neural pathways, reshaping its structure[147] and the way we think. This adaptability highlights the dynamic nature of thought processes, demonstrating that our thoughts can evolve and be reshaped over time.

This dynamic and adaptive nature of the brain sets the stage for understanding the multifaceted role of the Default Mode Network in orchestrating complex thought processes. Just as neural plasticity illustrates the brain's capacity to rewire and evolve, the DMN exemplifies how specific neural networks contribute to the ever-changing landscape of our thoughts, underlining the complexity and fluidity inherent in the way we think and process information. Traditionally associated with restful introspection and regarded as a task-negative network,[148] recent research reveals the DMN, 'a set of brain regions that exhibits strong low-frequency oscillations coherent during resting state and is thought to be activated when individuals are focused on their internal mental-state processes, such as self-referential processing, interoception, autobiographical memory retrieval, or imagining future',[149] is more active and pivotal role in various complex cognitive tasks, being involved in creative and integrative tasks, challenging the traditional binary view of its functionality and suggesting a broader role than just mind-wandering and self-referential thinking in cognition.[150] Studies utilizing fMRI have shown that the DMN is actively engaged during tasks that require creative problem-solving and the integration of information from diverse cognitive domains.[151] For instance, in tasks that necessitate the synthesis of disparate ideas or the generation of novel solutions, the DMN demonstrates heightened activity, indicating that the network

[146] Matt Puderbaugh, "Neuroplasticity," StatPearls - NCBI Bookshelf, May 1, 2023, https://www.ncbi.nlm.nih.gov/books/NBK557811/.
[147] Content Team, "What Happens to Your Brain When You Learn a New Language? - Unbabel," Unbabel, February 19, 2019, https://unbabel.com/what-happens-to-your-brain-when-you-learn-a-new-language/.
[148] Zilu Ma, Yuncong Ma, and Nanyin Zhang, "Development of Brain-Wide Connectivity Architecture in Awake Rats," NeuroImage 176 (August 1, 2018): 380–89, https://doi.org/10.1016/j.neuroimage.2018.05.009.
[149] Hamed Ekhtiari et al., "Neuroscience of Drug Craving for Addiction Medicine," in Progress in Brain Research, 2016, 115–41, https://doi.org/10.1016/bs.pbr.2015.10.002.
[150] Jonathan Smallwood et al., "The Neural Correlates of Ongoing Conscious Thought," iScience 24, no. 3 (March 1, 2021): 102132, https://doi.org/10.1016/j.isci.2021.102132.
[151] Nerissa Siu Ping Ho et al., "Facing up to the Wandering Mind: Patterns of off-Task Laboratory Thought Are Associated with Stronger Neural Recruitment of Right Fusiform Cortex While Processing Facial Stimuli," NeuroImage 214 (July 1, 2020): 116765, https://doi.org/10.1016/j.neuroimage.2020.116765.

contributes to the cognitive process of connecting previously associated concepts, a key aspect of creative thinking. Understanding the DMN's involvement in complex cognitive tasks offers a deeper perspective on how thoughts, even those not directly task-related, are processed and represented in the brain.

Despite these advances, fully understanding thoughts from a neuroscientific perspective remains a challenge, given their inherently subjective nature, thus, from a cognitive neuroscientific standpoint, thoughts are not mere ephemeral entities; rather, they represent a culmination of various neural activities and interactions, reflecting the complexity of the human cognitive experience, emotional states[152], environmental stimuli[153], and individual differences in brain structure and function,[154]so 'the content of our thoughts and the form they take varies in a complex manner across people, places, and time'.[155]

4.2. Thought Patterns: A Cognitive Psychological Exploration of Emotion and Action

In cognitive psychology, thoughts are viewed as integral components of the broader cognitive process. Thoughts are seen as mental representations,[156] which are the internal constructs of the mind that represent external reality. These mental representations can take various forms, such as images, words, or concepts, and are influenced by our perceptions, experiences, and cultural context, being the thought the link between image and its attributes.[157] For instance, how we think about a particular situation is shaped not only by the sensory information we receive but also by how we interpret and process this information based on past experiences and preconceived notions. Each of these processes

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152 Chai Meei Tyng et al., "The Influences of Emotion on Learning and Memory," Frontiers in Psychology 8 (August 24, 2017), https://doi.org/10.3389/fpsyg.2017.01454.

153 Kathryn E. Schertz et al., "Environmental Influences on Affect and Cognition: A Study of Natural and Commercial Semi-Public Spaces," Journal of Environmental Psychology 83 (October 1, 2022): 101852, https://doi.org/10.1016/j.jenvp.2022.101852.

154 Jenny Gu and Ryota Kanai, "What Contributes to Individual Differences in Brain Structure?," Frontiers in Human Neuroscience 8 (April 28, 2014), https://doi.org/10.3389/fnhum.2014.00262.

155 Jonathan Smallwood et al., "The Neural Correlates of Ongoing Conscious Thought," iScience 24, no. 3 (March 1, 2021): 102132, https://doi.org/10.1016/j.isci.2021.102132.

156 Eric Margolis and Stephen Laurence, "The Ontology of Concepts—Abstract Objects or Mental Representations?1," Noûs 41, no. 4 (October 25, 2007): 561–93, https://doi.org/10.1111/j.1468-0068.2007.00663.x.

157 V.D. Shadrikov, S.S. Kurginyan, and Olga Martynova, "Psychological Studies of Thought: Thoughts about a Concept of Thought," ResearchGate, January 1, 2016, https://www.researchgate.net/publication/316546273_Psychological_studies_of_thought_Thoughts_about_a_concept_of_thought.

contributes uniquely: attention determines what information we focus on, memory allows us to draw on past experiences, perception interprets sensory data, and language gives structure to our thoughts. This integration illustrates how thoughts are not isolated occurrences but the result of complex interplay between different cognitive functions, as supported by several key studies. A Harvard study led by *Steven Frankland* and *Joshua Greene*[158] highlights how the brain constructs new thoughts by combining known concepts using adjacent regions in the left superior temporal lobe. This suggests a sophisticated mechanism where the brain dynamically integrates various cognitive elements, like known concepts and variables, to formulate new thoughts, underscoring the brain's capacity for flexibility and precision in thought formation, creating the possibility that the 'ability to use a series of repeatable concepts to formulate new thoughts may be part of what makes human thought unique'.[159]

This perspective encompasses how individuals perceive, memorize, remember, reason, and make decisions.[160] Perception is a critical gateway in thought formation, where sensory information is actively interpreted based on past experiences and knowledge, forming the basis of how we understand and engage with our environment. This process is highly individualized, with each person's unique experiences and cognitive biases shaping their perception, leading to a diversity in thought formation.[161] Memory's role in thought formation is multifaceted and crucial. It serves as a reservoir of past experiences and knowledge, which directly influences how we perceive and understand new information.[162] When we encounter new situations or data, our brains actively retrieve relevant memories to make sense of these experiences, a process both conscious and unconscious, and it plays a significant role in how we form thoughts. Memories are not static, they change each time we recall them, undergoing a process of reconsolidation where they can be modified based on new experiences or information.

[158] Steven Frankland and Joshua D. Greene, "An Architecture for Encoding Sentence Meaning in Left Mid-Superior Temporal Cortex," Proceedings of the National Academy of Sciences of the United States of America 112, no. 37 (August 24, 2015): 11732–37, https://doi.org/10.1073/pnas.1421236112.

[159] Peter Reuell and Harvardgazette, "How the Brain Builds New Thoughts," Harvard Gazette, October 5, 2015, https://news.harvard.edu/gazette/story/2015/10/how-the-brain-builds-new-thoughts/.

[160] Candina Jordan, "What Is Cognitive Psychology?," WebMD, June 13, 2022, https://www.webmd.com/mental-health/what-is-cognitive-psychology.

[161] "Processing under Pressure by Matthew J. Sharps," n.d., https://www.blue360media.com/michigan-penal-code-motor-vehicle-handbook-2021-fall-edition-pre-order-55.html.

[162] Sruthi Sridhar, Abdulrahman Khamaj, and Manish Kumar Asthana, "Cognitive Neuroscience Perspective on Memory: Overview and Summary," Frontiers in Human Neuroscience 17 (July 26, 2023), https://doi.org/10.3389/fnhum.2023.1217093.

This dynamic nature of memory means that our thoughts are continually being shaped and reshaped by both past and present experiences. Moreover, the ease with which we recall certain memories is influenced by our emotional responses to events.[163] Furthermore, thoughts have a substantial influence on behaviour. Psychological models, such as Cognitive Behavioural Theory,[164] highlight the cyclical nature of thoughts, emotions, and behaviours, suggesting that altering one's thought patterns can lead to changes in emotions and behaviour.

One of the key aspects of the dynamics of thoughts is their inherent subjectivity, something that is introduced by the subject, but not present in the perceived object.[165] Each individual's thought patterns are unique and influenced by personal experiences, cognitive biases, and the complexity of emotional states. This subjectivity makes thoughts deeply personal and challenging to quantify or measure objectively, as opposed to information.[166] Psychology, therefore, approaches thoughts with an emphasis on understanding the individual's perspective, using various methodologies such as introspection, self-reporting, and behavioural observation to study and interpret thought processes.

Under the perspective analysed, thoughts are conceptualized as complex mental constructs formed through the interplay of various cognitive unique processes, shaped by a combination of sensory perceptions, memories, experiences, and cultural influences. These mental representations reflect not just the external world but also the personal, subjective interpretations of that world, making them central to our understanding, decision-making, and behaviour. Thoughts, therefore, represent a dynamic and integral aspect of human cognition, therefore involves considering not only the individual mind, but also the wider social and cultural context in which the individual operates, being influenced by social and cultural factors in their thought processes, as these are not formed in isolation, but are moulded by social norms, cultural backgrounds, and the social interactions we experience.[167]

[163] Michelle Yarwood, "Cognitive Appraisal Theory," Pressbooks, n.d., https://psu.pb.unizin.org/psych425/chapter/cognitive-appraisal-theory/.
[164] Nhs Website, "Overview - Cognitive Behavioural Therapy (CBT)," nhs.uk, November 14, 2023, https://www.nhs.uk/mental-health/talking-therapies-medicine-treatments/talking-therapies-and-counselling/cognitive-behavioural-therapy-cbt/overview/.
[165] V.D. Shadrikov (n 156), page 564.
[166] Ibid.
[167] "People's Thoughts and Behaviors: Influence of Cultural and Social Factors | Free Essay Example," StudyCorgi, December 3, 2022, https://studycorgi.com/peoples-thoughts-and-behaviors-influence-of-cultural-and-social-factors/.

As we conclude determining the nature of thoughts, we pave the way for a pivotal discussion: exploring the origins of thoughts, whether they arise from the mind or the brain. This exploration is not just a philosophical query but a vital step in understanding the essence of human cognition and consciousness.

4.3. Thought as a Product of the Mind within the Physicality of the Brain

'There is much more in a human thought or memory than just raw brain data.'[168] The relationship between the mind and the brain, and the question of which precedes the other, has been a subject of extensive debate among scholars and philosophers for centuries and we still haven't come close to a consensus. *René Descartes*, a prominent figure in 17th-century philosophy, posited a dualistic approach where the mind and body are distinct entities, with the mind having primacy over the physical brain.[169] In dualism, the distinct experiences of physical reactions (like withdrawing a hand from a hot surface) and emotional responses (such as fear or distress) exemplify the separation between body and mind. This philosophy considers mental phenomena as fundamentally different from, yet interconnected with, physical brain processes, illustrating the dual nature of human existence. This view set the stage for ongoing discussions about the precedence of mental states over brain activity.

In modern times, neuroscientists like *Wilder Penfield* have explored the brain's role as a computational system, suggesting a more integrated relationship between the mind and the brain.[170] For example, in the article "A Neuroscience Levels of Explanation Approach to the Mind and the Brain,"[171] *Edmund Rolls* proposes a model where brain events and mental events are seen as different levels of explanation within a computational system, rather than one causing the other. This view is shared by *M.R. Bennett*[172] and *Jaegwon Kim*,[173] who have also contributed to the discourse on the

[168] Sara Latini, "To the Edge of Data Protection: How Brain Information Can Push the Boundaries of Sensitivity A Doctrinal Legal Analysis of EEG and fMRI Neurotechnologies under EU Data Protection Law" (MA thesis, 2018).
[169] René Descartes, Meditations On First Philosophy, 1641, https://yale.learningu.org/download/041e9642-df02-4eed-a895-70e472df2ca4/H2665_Descartes%27%20Meditations.pdf.
[170] Rahul Kumar and Vikram K. Yeragani, "Penfield - A Great Explorer of Psyche-Soma-Neuroscience," Indian Journal of Psychiatry 53, no. 3 (January 1, 2011): 276, https://doi.org/10.4103/0019-5545.86826.
[171] Edmund T. Rolls, "A Neuroscience Levels of Explanation Approach to the Mind and the Brain," Frontiers in Computational Neuroscience 15 (April 7, 2021), https://doi.org/10.3389/fncom.2021.649679.
[172] M. R. Bennett, "Philosophical Foundations of Neuroscience," 2003, https://philpapers.org/rec/BENPFO-6.
[173] Jaegwon Kim, "Philosophy of Mind," 1996, https://philpapers.org/rec/KIMPOM-2.

interaction between mind and brain, particularly in the context of causality and the exclusion principle. There are also more transcendent theories, such as the quantum perspective of mind and consciousness, which argues that brain functions can go beyond classical biological interpretations and that quantum mechanical phenomena, such as entanglement and superposition,[174] can play a role in cognitive processes and consciousness,[175] a highly speculative and controversial theory, facing challenges in empirical verification and integration with established biological understandings of the brain. These diverse perspectives highlight the complexity of the mind-brain relationship, illustrating how the debate continues to evolve with advancements in both neuroscience and philosophical thought.

The debate over whether the brain is merely a processor of thoughts as mental states or their creator, is central to understanding the intricate relationship between the brain and the mind, but also to grant the corresponding protection to the data that comes from them. If the brain is seen as a processor, it implies that mental states exist independently of brain activity, merely being translated, or interpreted by the brain. This aligns with dualistic theories which view the mind and body as distinct, raising profound questions about the origins and essence of consciousness, [176] and suggesting a metaphysical aspect of mental states that transcends physical brain processes. Conversely, if the brain is regarded as the creator of mental states, it aligns with a physicalist or materialist view, seeing mental states as emergent properties of neural activity, inseparable from the brain's physical processes,[177] postulating that mental states are not byproducts of neural activity but exist in a realm that precedes and transcends it. In this framework, the brain functions like a sophisticated computer,[178] interpreting and translating pre-existing mental phenomena into neurological signals. This challenges the traditional neuroscientific paradigm that views brain activity as the genesis of mental experiences, re-evaluating the causal relationship between mind and brain and prompting a deeper exploration into the nature of consciousness. It suggests that thoughts and

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[174] De Voorhoede, "Superposition and Entanglement," Quantum Inspire, n.d., https://www.quantum-inspire.com/kbase/superposition-and-entanglement/.

[175] Unbounded Brain, "Human Brain — a Multidimensional Quantum Orchestra?," Medium, March 16, 2022, https://unboundedbrain.medium.com/human-brain-a-multidimensional-quantum-orchestra-49d0ec6129a7.

[176] "Dualism (Stanford Encyclopedia of Philosophy)," September 11, 2020, https://plato.stanford.edu/entries/dualism/.

[177] Jan Scheffel, "On the Solvability of the Mind–Body Problem," Axiomathes 30, no. 3 (August 2, 2019): 289–312, https://doi.org/10.1007/s10516-019-09454-x.

[178] In 'Penfield, W. (2015). *Mystery of the Mind*, Princeton University Press', it was considered that the brain is a literal computer which gets programmed by the mind.

emotions might have a non-physical essence processed and manifested through the brain's biological machinery.

The implications of each perspective are vast, influencing our understanding of human cognition, the nature of consciousness, and even the ethical considerations surrounding neurotechnologies like Brain-Computer Interfaces. Thus, determining whether the brain is a processor or creator of mental states is not just a theoretical exercise but a fundamental inquiry with wide-ranging consequences for our comprehension of the human condition.

4.3.1. Property Dualism and the Lack of Causal Interaction

Understanding the advantages and disadvantages of the physicalist and dualist theories,[179] it would seem more pacifying and logical to integrate certain elements of the two theories, that might refine 'one sort of substance or entity with both physical and phenomenal fundamental properties.'[180] Such combination would be referred to the already existing Theory of Property Dualism that represents a significant advancement in understanding the complex relationship between the mind, brain, and the dimension of thoughts.

'According to property dualism, there is one fundamental kind of thing in the world - material substance - but it has two essentially different kinds of property: physical properties and mental properties.'[181] Property dualism posits that mental states are unique and distinct properties. Unlike physical properties that can be measured and observed directly, mental properties encompass subjective experiences, thoughts, emotions, and consciousness. Water, in its diverse forms—liquid, solid (ice), and vapor (steam)—exemplifies property dualism. Each state, while distinctly exhibiting unique properties like fluidity, solidity, or gaseousness, fundamentally remains the same compound, H2O. This mirrors the brain in property dualism, where physical attributes (such as neural activity) and mental attributes (like thoughts or consciousness) are viewed as diverse yet

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179 See Jan Scheffel, "On the Solvability of the Mind–Body Problem," Axiomathes 30, no. 3 (August 2, 2019): 289–312, https://doi.org/10.1007/s10516-019-09454-x; Bill, "Strengths and Weaknesses of Dualism," AllAboutPhilosophy.Org (blog), September 28, 2006, https://www.allaboutphilosophy.org/strengths-and-weaknesses-of-dualism-faq.htm.

180 David John Chalmers, "Philosophy of Mind: Classical and Contemporary Readings," 2002, https://philpapers.org/rec/JCHPOM.

181 Elly Vintiadis, "Property Dualism," Pressbooks, September 10, 2019, https://press.rebus.community/intro-to-phil-of-mind/chapter/property-dualism/.

intrinsically linked manifestations of the same underlying brain structure. These are intrinsic to the mind's realm and are not fully explicable by physical laws. In this view, thoughts are not just electrical impulses or chemical reactions in the brain but possess a qualitative aspect that is fundamentally different. Despite their distinct nature, these mental states are seen as emergent from physical processes within the brain.[182] This emergence[183] is crucial to property dualism – it bridges the gap between the mental and the physical. According to this view, complex brain activity gives rise to mental phenomena, but these phenomena are not wholly reducible to neural processes. It's like how the melody of a symphony emerges from the combination of individual notes played by an orchestra, the melody cannot be found in any single note but is not independent of them either. Similarly, thoughts emerge from the brain but possess an 'extra' quality that brain processes alone cannot fully explain.

In this theory, thoughts are conceptualized as originating within the mind. They are more than outputs of brain activity, they are part of a mental landscape that includes beliefs, desires, and feelings. This view acknowledges that our mental life is not just a byproduct of brain function but has its own reality. For example, the experience of falling in love involves complex brain activity, but the subjective feeling of love is a mental state that can't be wholly equated to these physical processes. Thoughts, in this perspective, are mental events that originate from this internal mental landscape. After originating in the mind, thoughts are processed by the brain. This is where property dualism intertwines with neuroscience. The brain acts as an interface that translates these mental states into physical reactions and behaviours. This processing includes everything from the neural coordination required for speaking a thought out loud, to the physiological changes accompanying an emotion. The brain's role in this is crucial; it's the mechanism that allows the internal world of the mind to interact with the external physical world.

On the basis of what has been transmitted, the mind and brain are seen as interdependent yet maintain distinct characteristics. This interdependence acknowledges that mental states are not completely detached from physical reality - they need the brain to manifest and influence the world. Yet, their distinct nature in property dualism allows

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[182] "Mental Causation (Stanford Encyclopedia of Philosophy)," February 2, 2023, https://plato.stanford.edu/entries/mental-causation/.

[183] For more information regarding the understanding of consciousness and mind from an emergentist perspective see Evan Thompson, Mind in Life Biology, Phenomenology, and The Sciences of Mind (First Harvard University Press paperback edition, 2010).; Hasker, William. The Emergent Self. Cornell University Press, 1999. http://www.jstor.org/stable/10.7591/j.ctvkjb3fx.

for a non-reductionist view of human consciousness and experience.[184] It suggests that while our mental life is rooted in the physical, it reaches beyond it, encompassing aspects of our existence that physical explanations alone cannot fully capture,[185]respecting the complexity of human experience, recognizing both the physical basis of our mental life and its transcendent aspects.[186] Regardless of all the above, there are a number of criticisms that greatly weaken this theory.

One of the central challenges for Property Dualism is the interaction problem of mental causation.[187] If mental properties are distinct from physical properties, as property dualism asserts, how do they interact with the physical brain? This issue becomes particularly pressing when considering that physical processes are generally thought to be closed under physical laws. If mental properties are non-physical, their ability to causally affect physical processes, like neural activities, seems mysterious and inexplicable within the current scientific framework. This problem raises questions about the coherence of the theory, especially in light of the principle of causal closure in the physical sciences,[188] which posits that physical events are fully caused by other physical events. Neuroscientific research increasingly suggests that mental states, including thoughts and consciousness, are intimately connected to brain states. Functional neuroimaging techniques, like fMRI and PET scans, have shown correlations between mental activities and specific patterns of brain activity.[189] These findings support a more monistic or physicalist view of the mind-brain relationship, where mental phenomena are seen as emergent properties of physical processes in the brain. This perspective aligns with the empirical nature of neuroscience, which seeks to understand mental phenomena through observable brain activities, so the adoption of this theory, by introducing a non-

[184] "Consciousness is not merely another way of categorizing states of the brain or of behaviour, but a genuinely emergent phenomenon" in "Dualism (Stanford Encyclopedia of Philosophy)" (n 175).
[185] Elly Vintiadis (n 180).
[186] Libretexts, "Property Dualism -- Introduction to Philosophy: Philosophy of Mind," Humanities LibreTexts, March 10, 2021, https://human.libretexts.org/Bookshelves/Philosophy/Introduction_to_Philosophy_-_Philosophy_of_Mind_(Salazar_Ed.)/Property_Dualism_--_Introduction_to_Philosophy%3A_Philosophy_of_Mind.
[187] Elly Vintiadis (n 180).
[188] Dejan Dimitrijević, "Causal Closure of the Physical, Mental Causation, and Physics," ResearchGate, October 3, 2019, https://www.researchgate.net/publication/336242901_Causal_closure_of_the_physical_mental_causation_and_physics.
[189] Amirouche Sadoun et al., "Intensity Patterns at the Peaks of Brain Activity in fMRI and PET Are Highly Correlated with Neural Models of Spatial Integration," European Journal of Neuroscience 54, no. 9 (October 12, 2021): 7141–51, https://doi.org/10.1111/ejn.15469.

physical realm not accessible to empirical investigation, could hinder the integration of neuroscientific findings into a cohesive understanding of the mind.

Moving away from the dualism property theory, which separates mind and matter, we believe that it is needed to transition towards a more integrative approach, combining the Theory of Non-Reductive Physicalism and the Theory of Functionalism that we will analyse in the following chapter. By embarking on a "Integrated Functional Physicalism", we can acknowledge the physical basis of mental phenomena while also recognizing their unique, non-physical aspects, offering a more comprehensive understanding of the mind-brain relationship.

4.3.2. Integrated Functional Physicalism: Unravelling the Mind's Role in Thought Genesis

Non-Reductive Physicalism is a theory in the philosophy of mind that addresses the relationship between the mind and the physical aspects of the brain. It posits that while mental states are indeed physically grounded, they cannot be completely explained by physical properties alone, just like a computer. The software (programs, applications) cannot operate without the hardware (physical components like the CPU, hard drive). Yet, the software is not simply the sum of the hardware components; it has its own rules and functions. Similarly, thoughts and consciousness (akin to software) are dependent on the brain (akin to hardware) but are not just a direct product of it. This perspective views mental states as emerging from brain activities but asserts that they possess unique, non-physical properties that set them apart from mere biological functions. Emergentism is fundamentally about the existence of physical systems that exhibit properties not found in their constituent parts, and these properties cannot be reduced to or explained solely by the properties of these parts. This perspective views the physical world as a hierarchy of events, where each level - microphysical, biological, mental, social - contributes to more complex forms at the higher levels.[190] For example, the emergentist perspective recognizes that a mental process, such as consciousness, is not just a neural process but something more complex and differentiated, arising from but not reducible to neural

[190] Juan Diego Morales, "Nonreductive Physicalism: Understanding Our Metaphysical Paradigm," ResearchGate, December 15, 2015, https://www.researchgate.net/publication/236035306_Nonreductive_physicalism_understanding_our_metaphysical_paradigm.

activities. This aligns with what *Fodor* describes as token physicalism,[191] which states that all events discussed by the sciences are physical, yet this view is criticized for being compatible with property dualism.[192]

In this framework, mental phenomena like thoughts, emotions, and consciousness are more than the sum of physical brain processes, because these phenomena have qualitative experiences and properties that cannot be reduced to, or wholly explained by, physical laws. This theory respects the integrity of physical science in explaining the brain's functioning while simultaneously acknowledging the depth and complexity of mental experiences beyond the physical realm. Transitioning from Non-Reductive Physicalism, which emphasizes the physical yet distinct nature of mental states, we now turn to explore Functionalism, a theory that further elaborates on how these mental states operate within the broader context of cognitive processes and interactions.

Functionalism in the philosophy of mind is a theoretical framework that focuses on the functions or roles of mental states, rather than their internal composition or how they are physically realized in the brain. See the example of the smartphone, which can be used for various functions like making calls, sending texts, or browsing the internet. These functions are not tied to the specific hardware of the phone but rather to the software it runs. Similarly, in functionalism, mental states are defined by their function or role in the cognitive system, not by their underlying physical substrate. Just as different phones can perform the same functions, different physical substrates (like brains) can realize the same mental states. So, this perspective posits that what defines a mental state is not its physical substrate but the role it plays within a cognitive system.[193] For example, a mental state like 'pain' is identified not by its neurophysiological features but by how it functions in the organism – its causes (like tissue damage), and its effects (like withdrawal from harm, distress, and pain behaviour).[194] This approach allows for a broad interpretation of mental states, suggesting that they could be realized in multiple ways, across different kinds of beings or even machines, if the functional role is fulfilled.

This theory, therefore, brings a level of abstraction to the study of the mind, concentrating on the systemic and relational aspects of mental phenomena. It addresses

[191] Jerry A. Fodor, "Special Sciences (or: The Disunity of Science as a Working Hypothesis)," Synthese 28, no. 2 (October 1, 1974): 97–115, https://doi.org/10.1007/bf00485230.
[192] Juan Diego Morales (n 189), page 34.
[193] Hilary Putnam, "Minds and Machines," 1960, https://philarchive.org/rec/PUTMAM.
[194] "Multiple Realizability, Mind and | Internet Encyclopedia of Philosophy," n.d., https://iep.utm.edu/mult-rea/.

how mental states interact with sensory inputs, other mental states, and behavioural outputs. Functionalism in philosophy of mind identifies mental states by their causal roles within an organism, focusing on the causes and effects of these states. We can also conclude that diverse physical states in different species can perform similar functions, leading to equivalent mental states, positioning functionalism within the non-reductive physicalism framework, which recognizes mental properties as unique yet physically grounded.[195] It is particularly appealing for its compatibility with the idea of artificial intelligence, as it suggests that mental states could, in theory, be instantiated in non-biological systems that exhibit similar functional patterns. In essence, functionalism decouples the mind from a strictly biological basis, emphasizing instead patterns of interaction and the roles played by various mental processes. This perspective has been influential in cognitive science, where understanding the 'software' of the mind often takes precedence over the 'hardware' of the brain.[196]

If we join the two theories presented, which, in our opinion, represent the proper angle on the mind-brain relationship, we find a theory of an Integrated Functional Physicalism, conceptualizing thoughts as originating from the mind's emergent properties and functional capacities, while emphasizing the mind's role in cognitive systems, distinct from the brain's physical mechanisms. This integrated approach recognizes that while thoughts have a physical basis in brain activity, they are not entirely confined to physical properties. It combines the idea of functional roles from Functionalism with the emergent properties aspect of Non-Reductive Physicalism, suggesting that thoughts are products of both the brain's physical processes and the mind's complex, functional interactions within the cognitive system. This theory thus provides a nuanced view of thoughts as entities shaped by both their physical underpinnings and their roles in cognitive functioning. The mind, in this sense, is a product of the brain but operates at a level that includes functions and properties not entirely reducible to physical brain processes, that enables and processes thoughts without reducing them to mere physical phenomena. Therefore, we see the brain as a facilitator of thought processes, supporting and realizing the mind's cognitive functions and emergent properties, but not being the sole originator of thoughts themselves.

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[195] "Study Guide Philosophy of Mind: Non-Reductive Physicalism," NILS' PHILOSOPHY PAGE, n.d., https://nilskurbis.weebly.com/non-reductive-physicalism.html.

[196] Kanchan Roy, "A Discussion on Computational Functionalism of Mind," Www.Academia.Edu, November 3, 2018, https://www.academia.edu/37697725/A_discussion_on_Computational_Functionalism_of_Mind.

Neural activity in the brain forms the substrate from which thoughts emerge, suggesting a causal link between brain function and the generation of thoughts, but just as these have emerged, they are not simply reduced to their neurological underpinnings, occupying a distinct realm within the mind, characterized by subjective experience and qualitative richness that neural processes alone cannot fully encapsulate. The brain then engages in further processing of these thoughts, integrating them with sensory input, emotional states, and memories. This processing, while rooted in the physical, navigates and influences the realm of the mental, reflecting the dual nature of human cognition as both a physical and a mental phenomenon.

4.4. A Unified Concept of Thought

To trace a comprehensive concept of thoughts, integrating the perspectives presented is key. From a neuroscientific standpoint, thoughts are understood as the outcome of complex neural processes within the brain. This includes neural networks engaging in the transmission and processing of information, which is evident in various brain imaging studies as mentioned. Neuroscientists examine the brain's physical and chemical processes to understand how thoughts are formed, mapping specific brain regions and activities associated with different types of thinking. In contrast, the psychological perspective focuses on the subjective experience of thoughts and their role in human behaviour and cognition. This includes understanding how thoughts are influenced by factors like memory, perception, attention, and language. Psychology delves into how thoughts shape our understanding of the world, influence our decisions, and affect our emotional responses. It considers the content of thoughts, their patterns, and how they contribute to mental health and well-being. Finally, from a philosophical viewpoint, specifically within the framework of Integrated Functional Physicalism, thoughts are conceptualized as originating in the mind, not as direct products of brain activity, suggesting that while the brain facilitates the process, the mind is where thoughts actually form. It underscores the mind's emergent properties and functional capacities, highlighting a more abstract and complex origin of thoughts, beyond the brain's physical processing capabilities.

Combining these perspectives, we see that thoughts are a multifaceted phenomenon: they are rooted in the brain's neural processes, experienced and interpreted through the lens of psychological processes, and ultimately originate in the mind's complex, abstract realm. This integrated approach provides a holistic understanding of thoughts, acknowledging their biological basis while also recognizing their deeper, non-reducible nature in the human experience. This integrated perspective acknowledges that thoughts are not just the product of brain activity, but rather the *a priori* cause of manifested brain activity, which involves complex cognitive functions, emotional states, and individual experiences. So, we can identify that thoughts are dynamic, continuously evolving processes that are deeply rooted in both the biological functioning of the brain and the psychological aspects of cognition and emotion. Each individual's thought processes are a unique blend of their neural patterns, cognitive functions, emotional experiences, personal social constraints, but also information that are physically encoded in matter.[197]

The relevance of these findings in the context of BCI decoding is profound. The current state of neuroimaging and BCI technologies, as exemplified by studies like *Gallant* lab's fMRI-based image reconstruction[198] and *Moses* et al.'s ECoG-based speech dialogue decoding,[199] demonstrates significant progress in decoding the input and output signals of the brain. However, the true essence of 'thought' - what happens between these inputs and outputs - remains elusive. This gap in understanding underscores the challenges faced by BCIs in accurately interpreting and translating the intricate workings of the human mind. The realization that thoughts are not entirely constructible from electrical activity alone suggests that BCIs might need to evolve beyond current methodologies to fully capture and interact with human thought processes.

Having explored the intricate nature and cradle of thoughts, we now transition to examining the legal implications of these insights, specifically delving into the territory of personal data and its protection under the General Data Protection Regulation.

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[197] Ralph Lewis, "What Actually Is a Thought? And How Is Information Physical?," Psychology Today, October 2023, https://www.psychologytoday.com/us/blog/finding-purpose/201902/what-actually-is-a-thought-and-how-is-information-physical.

[198] Kendrick Kay et al., "Identifying Natural Images from Human Brain Activity," Nature 452, no. 7185 (March 1, 2008): 352–55, https://doi.org/10.1038/nature06713.

[199] David A. Moses et al., "Real-Time Decoding of Question-and-Answer Speech Dialogue Using Human Cortical Activity," Nature Communications 10, no. 1 (July 30, 2019), https://doi.org/10.1038/s41467-019-10994-4.

5. From Mind to Personal Data: The Legal Status of Thoughts under the GDPR

5.1. Brain and Neuronal Information Converted into Personal Data

The neuron's ability to generate an action potential, an electrical signal, and propagate it along the axon to the synapse, where it can trigger the release of neurotransmitters into the synaptic cleft, is fundamental to brain function. This synaptic transmission is the primary mechanism for neuron-to-neuron communication. The patterns and frequencies of these action potentials and the resulting neural networks they form are what we measure as neural data.

The technical explanation of the neurotechnology applied in the scientific study already reviewed[200] showed that the extrapolated information consists of two different components: (i) untouched physiological values that are manifested by the brain's electrical activity; (ii) the interpretation that experts make of the untouched values. These interpretations transform basic physiological measurements into crucial data that can be concerned to an individual's health status or, based on the particular brain regions analysed, their racial and ethnic[201] background. As such, ECoG signals, just like EEG signals, have no meaning in themselves; they need to be read and decoded in order to be translated into meaningful information about the individual. To utilize brain recordings effectively, it is necessary to isolate signals pertinent to a specific objective from the overall recorded data, which means, to render brain recordings practical for a specific use, they must undergo processing where key features are extracted and relevant signals are categorized based on identifiable characteristics of a certain brain activity that can be converted to data, digital data.

The General Data Protection Regulation, which came into effect on May 25, 2018, within the European Union, establishes a framework for the processing of personal data, 'in the context of the activities of an establishment in the EU regardless of whether the processing takes place in the Union or not',[202] under all the changes causes by the rapid

[200] It is important to remember that electrocorticography is an extremely important neurophysiological technique used in the operating room to monitor and map brain electrical activity.

[201] Peipeng Liang et al., "Construction of Brain Atlases Based on a Multi-Center MRI Dataset of 2020 Chinese Adults," Scientific Reports 5, no. 1 (December 18, 2015), https://doi.org/10.1038/srep18216.

[202] "Guidelines 3/2018 on the Territorial Scope of the GDPR (Article 3) - Version Adopted after Public Consultation | European Data Protection Board," n.d., https://edpb.europa.eu/our-work-tools/our-documents/guidelines/guidelines-32018-territorial-scope-gdpr-article-3-version_en.

development of technologies and globalisation.[203] It defines personal data as 'any information that relates to an identified or identifiable natural person',[204] being considered a "data subject". Personal data under the GDPR encompasses a wide range of information, including obvious subject identifiers such as names, identification numbers, and location data. It also covers less direct identifiers, like an online provided they can be used to identify a person when combined with other information, such as the 'physical, physiological, genetic, mental, economic, cultural or social identity of that natural person'.[205] Despite these references to physical, physiological, and mental identifiers, the GDPR does not explicitly mention brain or neural information. This raises a critical question: does the GDPR effectively address the unique challenges presented by brain information, or does it regard such data as typical personal data without necessitating special attention? Resolving this inquiry is essential, especially considering the fundamental role of data protection legislation in safeguarding individual privacy and setting the parameters for handling personal information of the data subjects.

To understand what sets brain information apart as a distinct category of personal data, it's essential first to examine if data derived from the human brain through the neurotechnologies fits within the EU's data protection legal framework's definition of personal data. The author *Dara Hallinan* and his colleagues have previously addressed this question under the Data Protection Directive[206] (DPD), analysing it as the term "neurodata". Given the DPD's broad scope, their conclusion was that neural data falls under the umbrella of personal data.[207] This broad approach in data protection law is intentional, designed to ensure robust protection of individual rights.[208] Consequently, the term "personal data" in EU law is interpreted expansively, covering almost any data

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[203] Recital 6 of the General Data Protection Regulation (n 23).
[204] Article 4(1) of the GDPR defines personal data as "any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person."
[205] Ibid.
[206] Official Journal of the European Communities, "Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the Protection of Individuals with Regard to the Processing of Personal Data and on the Free Movement of Such Data," 1995, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31995L0046.
[207] Dara Hallinan et al., "Neurodata and Neuroprivacy: Data Protection Outdated?," Surveillance and Society 12, no. 1 (November 20, 2013): 55–72, https://doi.org/10.24908/ss.v12i1.4500.
[208] Nadezhda Purtova, "The Law of Everything. Broad Concept of Personal Data and Future of EU Data Protection Law," Law, Innovation and Technology 10, no. 1 (January 2, 2018): 40–81, https://doi.org/10.1080/17579961.2018.1452176.

linked to an identifiable individual.[209] The development of the right to data protection, culminating in the adoption of the GDPR, has largely been driven by the need to align legal tools with societal and technological advancements. As a result, the scope of EU data protection law has expanded.[210] By applying this rationale to brain data and neural data under GDPR, which has an even wider scope than the DPD, the same conclusion emerges.

While there isn't an agreed definition of neural data,[211] the UNESCO International Bioethics Committee Report on Neurotechnology utilizes the term to describe it as 'personal brain data', [212] while the Council of Europe's Bioethics Committee identifies it as 'human brain data'.[213] Pursuant, also, to the Organisation for Economic Co-operation and Development understanding[214], personal brain or neural data are 'data relating to the functioning or structure of the human brain of an identified or identifiable individual that includes unique information about their physiology, health, or mental states'.[215] As for the Information Commissioner's Office is concerned, the concept of neural data is extended not only to information collected from the brain, but also from the nervous system, defining it as 'first order data gathered directly from a person's neural systems (inclusive of both the brain and the nervous systems) and second order inferences based directly upon this data'.[216]

In our opinion, in the balance of the two definitions identified above, the concept of neural data used by the ICO is more complete, largely sufficient for the protection of the intended personal data of the subjects, with regard to the range of personal data involved in the brain, but it is also the most applicable to the reality in question. The definition given by UNESCO does not castrate other personal data that can be obtained by the brain, but it does imply that the data that can be obtained comes from physiological

[209] ARTICLE 29 DATA PROTECTION WORKING PARTY, "Opinion 4/2007 on the Concept of Personal Data," June 2007, https://www.clinicalstudydatarequest.com/Documents/Privacy-European-guidance.pdf.
[210] See Recital 6 of the GDPR.
[211] Information Commissioner's Office, "ICO Tech Futures: Neurotechnology," June 2023, https://ico.org.uk/media/about-the-ico/research-and-reports/ico-tech-futures-neurotechnology-0-1.pdf.
[212] Report of the International Bioethics Committee of UNESCO (n 9).
[213] See Report commissioned by the Committee on Bioethics (DH-BIO) of the Council of Europe (n 11), page 23: "These quantitative data about the structure, activity and function of the human brain can be called 'human brain data'. Human brain data can reveal information about a person health status (e.g., neurological, or psychiatric health) and, to some extent, support inferences about mental processes".
[214] Hermann Garden et al., "Responsible Innovation in Neurotechnology Enterprises," OECD Science, Technology and Industry Working Papers, October 11, 2019, https://doi.org/10.1787/9685e4fd-en.
[215] "OECD Legal Instruments," n.d., https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0457.
[216] Information Commissioner's Office (n 210).

or health data. The problem actually lies in the consideration of "mental states"[217] as brain/neural data, when these states are more appropriately inferred from the mind, being referred to a range of cognitive conditions and processes, but not exclusively, as we will see further ahead. Brain data processing involves various methods, including adaptive, unsupervised processes, where purpose-specific information is extracted from general brain activity recordings, which comes from brain states. This processing can yield diverse information from the same recording for different purposes, and adaptive filtering and classifying may evolve, potentially revealing more or different information than initially intended by researchers or users, opening a window to the potential of brain recordings to predict user behaviour, brain states, and identity-related activities[218] that needs data protection and privacy scrutiny, leading to increasing calls for international regulation as consumer neurotechnology gains broader market entry.[219]

Effectively, brain data gives us insight into the macro-level activities and states of the brain, but also draws us into the micro-level, revealing the intricacies of how neurons communicate and function, offering a detailed lexicon of the brain's language - encoded in action potentials and synaptic transmissions, through the neural system, acting as the granular manifestation of the brain's activity, capturing the bioelectrical and biochemical phenomena that constitute the essence of neural processing. But what has been shown is that, regardless of the definition that can be attributed to neural data, it is not sufficient for data that comes from a combination of various internal factors that interrelate the neuronal connections with phenomenon that are rooted in the brain's neural processes, experienced and interpreted through the lens of psychological processes, and ultimately originate in the mind's complex, abstract realm like thoughts.

The already mentioned UNESCO's report, states that 'the specificity of brain data lies in the inferences that can be drawn from their analysis about actual consciousness, emotional state or even thoughts'.[220] What actually transpires from this statement is that the brain data comes from the information obtained through an analysis not only of consciousness and psychological/emotional state, but also through thoughts, necessarily

[217] "We define 'mental state' any conglomeration of mental representations and propositional attitudes that corresponds to the experience of thinking, remembering, planning, perceiving, and feeling" in Marcello Ienca and Gianclaudio Malgieri (n 28)
[218] Philipp Kellmeyer, "Big Brain Data: On the Responsible Use of Brain Data from Clinical and Consumer-Directed Neurotechnological Devices," Neuroethics 14, no. 1 (May 19, 2018): 83–98, https://doi.org/10.1007/s12152-018-9371-x.
[219] Marcello Ienca, Pim Haselager, Ezekiel Emanuel (n 29).
[220] Report of the International Bioethics Committee of UNESCO (n 9) page 36.

making the brain data later than the true core of the information, creating the possibility of being accused that thoughts represent a distinct type of data surpassing traditional brain data or the neural system claimed by the ICO report. This is because thoughts, as inferred from brain data, encompass elements of consciousness and emotional states, making them more complex and intimately connected to an individual's personal and subjective experience. Additionally, this complexity and depth might position thoughts as a unique category of data inserted in mental data, with implications that extend beyond the physiological or structural aspects typically associated with brain data, considering that (i) mental data is not brain data, since information about mental states and processes can be inferred from non-neural data, such as behavioural data; and (ii) not all brain data is mental data, since brain data can be processed to infer not only mental states, but also the basic anatomy and physiology of the brain, without revealing anything related to mental states and processes.[221]

5.2. Deciphering Thoughts: Distinguishing Mental Data from data collected by "Mind-Reading" BCI Technology

'The term 'mind-reading' has been used to describe the mechanisms employed by BCIs and neural decoding using neurotechnologies.'[222] Can we really say that BCIs are performing mental data reading, accessing our thoughts, and thus reading our mind? BCIs can decode neural activity associated with specific mental states or intentions, such as imagined speech or movement intentions. This procedure has been popularized as "mind-reading"[223], but it generally just entails the creation of dependable statistical correlations between brain activity, function, structure, and mental information, such decoding is based on identifying patterns in brain activity and is not equivalent to accessing or "reading" the full complexity of subjective thoughts, manifesting itself in the translation of specific brain signals into actionable results rather than understanding the subjective and nuanced content of thoughts.

[221] Marcello Ienca and Gianclaudio Malgieri (n 28), page 7.
[222] Stephen Rainey et al., "Brain Recording, Mind-Reading, and Neurotechnology: Ethical Issues from Consumer Devices to Brain-Based Speech Decoding," Science and Engineering Ethics 26, no. 4 (April 30, 2020): 2295–2311, https://doi.org/10.1007/s11948-020-00218-0.
[223] Matthias Gamer, "Mind Reading Using Neuroimaging," European Psychologist 19, no. 3 (January 1, 2014): 172–83, https://doi.org/10.1027/1016-9040/a000193.

Mind-reading surpasses the brain data awaiting to be interpreted by the BCI, attempting to interpret it in order to identify the human emotions, intentions, memories, or thoughts.[224] If we take the scientific study presented, as well as others, but with less positive results,[225] a speech decoder Brain-Computer Interface focus specifically on interpreting the neural mechanisms associated with speech production rather than the subjective experience of thought. These BCIs utilize advanced algorithms to analyse patterns of brain activity, particularly those that occur during speech or speech-related processes. The technology effectively maps these neural patterns to corresponding speech sounds or textual representations. However, it does not delve into the personal, subjective content of thoughts or emotions. The capability of these systems is grounded in the physical realm of brain activity, translating specific neural signals into speech or text, and not in interpreting or 'reading' the abstract, subjective nature of individual thoughts or internal mental states, which proves the point, for now, that the technology still available is unable to gauge information directly from thoughts, unless we do get a Mind-Computer Interface.

Ienca and *Malgieri* define mental data as ‘any data that can be organized and processed to infer the mental states of a person, including their cognitive, affective, and conative states’.[226] Furthermore, mental representations are the closest psychological and neurobiological substrate for fundamental ethical-legal notions such as freedom of thought, personal identity, personal autonomy, mental integrity and others.[227] Thoughts, as part of mental representations, form an integral part of an individual's psychological makeup and are essential to their sense of self and autonomy. Therefore, thoughts as mental data are not only central to cognitive processes but are also fundamental to the core aspects of safeguarding human rights and personal freedom.

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[224] Kathinka Evers and Mariano Sigman, “Possibilities and Limits of Mind-Reading: A Neurophilosophical Perspective,” Consciousness and Cognition 22, no. 3 (September 1, 2013): 887–97, https://doi.org/10.1016/j.concog.2013.05.011.

[225] Brumberg, “Classification of Intended Phoneme Production from Chronic Intracortical Microelectrode Recordings in Speech-Motor Cortex,” Frontiers in Neuroscience, May 12, 2011, https://doi.org/10.3389/fnins.2011.00065; Stéphanie Martin et al., “Word Pair Classification during Imagined Speech Using Direct Brain Recordings,” Scientific Reports 6, no. 1 (May 11, 2016), https://doi.org/10.1038/srep25803.

[226] Marcello Ienca and Gianclaudio Malgieri (n 28), page 4.

[227] Caplan A. L. (2017). Joseph J. Fins' Rights Come to Mind: Brain Injury, Ethics and the Struggle for Consciousness. Cerebrum: Orsolya Friedrich et al., “An Analysis of the Impact of Brain-Computer Interfaces on Autonomy,” Neuroethics 14, no. 1 (April 18, 2018): 17–29, https://doi.org/10.1007/s12152-018-9364-9.

5.3. Thoughts as Personal Data

If we return to the concept of personal data under the GDPR,[228] it can be divided into four cumulative requirements: (i) 'any information'; (ii) 'relating to'; (iii) 'an identified or identifiable'; (iv) 'individual'. In order to understand whether thoughts can be personal data under the Regulation, let's take a closer look at the fulfilment of the requirements.

The concept of 'personal data' under GDPR is intentionally broad, encompassing 'any information' even seemingly trivial data.[229] Personal data includes both objective and subjective information, in form of opinions for example,[230] whether it concerns private life, professional activities, or social behaviour, and does not need to be true, proven, or complete,[231] as long as it is related to a person. This definition covers all forms of data, regardless of medium, adhering to a technology-neutral approach, safeguarding all data types, ensuring robust privacy rights. Considering the fact that the GDPR is prepared to include information that is considered subjective, it is not opposed to considering the nature of thoughts as a statement about any person which takes the form of reading and interpreting information.

The European Regulation requires that information must pertain – 'relating to' - to an individual to be considered personal data. The CJEU, guided by WP29,[232] states that the information's content, purpose, or effect must be linked to a specific person,[233] i.e., if it directly concerns the particular individual or allows inferences about them, like wealth from property value or driving behaviour from car service records.[234]Central to the application of personal data is the capacity to identify directly or indirectly, the data subject, a concept known as linkability.[235] When defining the scope of personal data and assessing linkability, there is scholarly debate over the use of 'objective' versus 'relative'

[228] Article 4(1) of the General Data Protection Regulation (n 23).
[229] COMMISSION OF THE EUROPEAN COMMUNITIES, "COM(90) 314 Final - SYN 287 and 288 Brussels," September 1990, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:51990DC0314.
[230] ARTICLE 29 DATA PROTECTION WORKING PARTY (n 208), page 6.
[231] Ibid.
[232] Ibid, page 10.
[233] Judgment Of The Court (Second Chamber), Case C-434/16, Peter Nowak v Data Protection Commissioner, 2016. Available at: https://curia.europa.eu/juris/document/document.jsf?text=&docid=198059&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=1067970.
[234] ARTICLE 29 DATA PROTECTION WORKING PARTY (n 208), page 10.
[235] Judgment of the Court (Second Chamber), "Peter Nowak v Data Protection Commissioner in Case C-434/16," (n 27), [61]-[63].

criteria.[236] When considering the protection of thoughts as personal data, the abstract theory, or objective criterion, emerges as the more suitable approach. This theory advocates that personal data encompasses all information potentially linkable to an individual, independent of the particular context or the specific knowledge of the data processor or controller.[237] Such an inclusive definition is crucial for thoughts, given their deeply personal and intricate nature. Thoughts encapsulate a person's innermost experiences and ideas, which, if not broadly protected, could be vulnerable to misuse or exploitation. The concrete theory, or relative criterion, in comparison, bases personal data designation on the ability of a specific actor to associate the data with an individual in given circumstances.[238] This narrower view could lead to inconsistent protection of thoughts, as it hinges on the varying capabilities and resources of different data processors. By adopting the abstract theory, a more uniform and expansive safeguard is provided, ensuring that thoughts are consistently recognized and protected, thus minimizing their potential exploitation for economic or other purposes.

Identification of a data subject, a key GDPR component, hinges on whether the person is 'identified or identifiable.' Identification occurs through unique characteristics like name, location, or physical traits, not necessarily requiring a person's name, as other identifiers may be more distinctive.[239] Identifiability involves potential identification through information combinations.[240] This assessment considers various factors like technology and resource availability, emphasizing the realistic likelihood of identification rather than mere hypothetical possibilities. For instance, in the Breyer v Germany case, mentioned on the footnotes, the CJEU deliberated on IP addresses as personal data, illustrating how context influences data classification. This ruling suggests that dynamic IP addresses can be personal data when additional details enable individual identification.[241] This case extends beyond IP addresses, potentially widening the scope of data needing protection. The focus on the possibility, not the probability, of identification implies that data types like identifiers in neurotechnology, unless entirely

[236] JUDGMENT OF THE COURT (Second Chamber), "Patrick Breyer v Bundesrepublik Deutschland in Case C-582/14 (n 26).
[237] Oskar Josef Gstrein, "Mobile Devices as Stigmatizing Security Sensors: The GDPR and a Future of Crowdsourced 'Broken Windows,'" 2018, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3105228.
[238] Ibid.
[239] See ARTICLE 29 DATA PROTECTION WORKING PARTY (n 208), page 12.
[240] Ibid.
[241] JUDGMENT OF THE COURT (Second Chamber), "Patrick Breyer v Bundesrepublik Deutschland in Case C-582/14" (n 26), [49].

anonymized, might be deemed personal data under GDPR, as anonymization would negate the functional purpose of consumer neurotechnology devices.[242] Based on this ruling it's plausible to argue that thoughts could be identified or identifiable with the data subject. If thoughts, as interpreted by neurotechnology, can be combined with other information that identifies the specific individual, creating an inter dependency and connecting between the data subject and the technology. This aligns with the CJEU's emphasis on the potential for identification, rather than the direct identification, broadening the scope of what may be categorized as personal data. For example, if a brain recording device is designed to respond to unique brain signals of a user for device control, it needs to be specifically calibrated for that individual.[243] The device's classification or filtering algorithms will then function in a manner tailored to the user's distinct brain patterns. In such cases, the use of these calibrated algorithms creates a direct link between the data set and the specific user, allowing a data controller to associate the algorithm's operation with the individual data subject. Extending this logic to thoughts, if such devices can interpret and respond to individual thought patterns, then those thoughts, like the brain signals, could potentially be linked to a specific user. This implies that in certain contexts, thoughts can be identifiable and thus may fall under the scope of personal data as defined by GDPR.

The right to data protection under Article 8 of the EU Charter of Fundamental Rights[244] applies to all natural persons, not limited by nationality. This protection typically extends from birth until death,[245] with deceased persons' data generally not considered personal.[246] However, member states may enact rules to protect deceased persons' data, and genetic data may indirectly receive protection through relatives. Information on legal entities is usually not personal data,[247] but exceptions exist, especially when such data can reveal details about natural persons, like in small or family-run businesses, where company information might relate to an individual. The factor of a natural person being central to the definition of personal data under GDPR directly applies to thoughts as personal data. Since thoughts are inherently personal and originate from

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[242] Stephen Rainey et al. (n 33), page 7.
[243] Dennis J. McFarland and Jonathan R. Wolpaw, "Brain–Computer Interface Use Is a Skill That User and System Acquire Together," PLOS Biology 16, no. 7 (July 2, 2018): e2006719, https://doi.org/10.1371/journal.pbio.2006719.
[244] United Nations, "Universal Declaration of Human Rights | United Nations," n.d., https://www.un.org/en/about-us/universal-declaration-of-human-rights.
[245] ARTICLE 29 DATA PROTECTION WORKING PARTY (n 208), page 23.
[246] See Recital 27 of the General Data Protection Regulation (n 23).
[247] Ibid, Recital 14.

natural persons, they align with the GDPR's protection scope. This implies that any data, including thoughts, generated, processed, or inferred from a natural person's brain activity falls under the umbrella of personal data protection, provided it relates to an identifiable individual.

Under Article 4(1) of the GDPR thoughts inherently meet these requirements, as they provide information which is unique to individuals and can be linked to them, either directly or indirectly through neurotechnology. Thoughts reflect personal experiences, preferences, and emotions, making them distinctive to each person. Therefore, when captured, interpreted, or processed through technologies like BCIs, thoughts can be considered personal data as they provide identifiable information about a natural person, aligning with the GDPR's definition and scope. 'What remains is a discussion of how significant this data may be, how existing regulations ought to be interpreted, and what further regulation may be required'.[248] It could be argued that a thought does not necessarily result in information that identifies, directly or indirectly, the data subject, but in fact the reasoning done would only result in an *a posteriori* consequence of the thought, because, as already discussed, thought is what lies in the middle between the input, the neuronal mechanism that reacts to the stimulus of individual experience, and the output, which manifests itself in the reading and interpretation of the information collected from the brain signals, as such, thought always comes from a singular procedure that uniquely identifies the individual, that is, personal data of the data subject. Furthermore, if it is proven that brain patterns captured through EEG or fMRI provide unique and personalised information about the individual,[249] and these are the result of a set of factors in the consequential interrelationship between the mind and the brain, then thoughts are also personal and identify the person.

Understanding that thoughts are personal data that fall within the scope of the General Data Protection Regulation, it is important to determine whether there is any category of data under discussion that can accommodate them.

[248] Stephen Rainey et al. (n 33), page 9.
[249] "Are Your Thoughts Your Own?:"Neuroprivacy" and the Legal Implications of Brain Imaging," Member & Career Services | NYC Bar, n.d., https://www.nycbar.org/member-and-career-services/committees/reports-listing/reports/detail/are-your-thoughts-your-ownneuroprivacy-and-the-legal-implications-of-brain-imaging.

5.4. Mental Data as a limit of the scope of sensitive data processing: CJEU Decision C-184/20

The next legal issue to consider is whether data related to the human mind can be classified as special categories of personal data. The user's privacy concerns and their willingness to disclose information are affected by the perceived sensitivity of that information,[250] and the advancements of technology entail the continuous creating of enormous amounts of personal data.[251] The General Data Protection Regulation defines sensitive data in the recital (51):

> *"Personal data which are, by their nature, particularly sensitive in relation to fundamental rights and freedoms merit specific protection as the context of their processing could create significant risks to the fundamental rights and freedoms".*[252]

However, various other factors also contribute to how users perceive the sensitivity of data. These include the perceived risk, potential for harm, and the public availability of the data, all of which can influence the perception of information as being sensitive.[253] The existing EU data protection framework, particularly the GDPR, has specific measures designed to offer enhanced protection for such special categories of personal data. These categories, due to their inherent nature, can significantly impact individuals' lives when processed,[254] and thus the GDPR ensures they receive additional safeguards, consequently the processing of sensitive data is permissible only under certain conditions and with the implementation of specific protective measures.[255] Accordingly to the article 9 (1) of the GDPR, special categories of data, also known as sensitive data,

[250] Ereni Markos, George R. Milne, and James W. Peltier, "Information Sensitivity and Willingness to Provide Continua: A Comparative Privacy Study of the United States and Brazil," Journal of Public Policy & Marketing 36, no. 1 (April 1, 2017): 79–96, https://doi.org/10.1509/jppm.15.159.
[251] Paul Quinn, "The Anonymisation of Research Data — A Pyric Victory for Privacy That Should Not Be Pushed Too Hard by the Eu Data Protection Framework?," European Journal of Health Law 24, no. 4 (October 19, 2017): 347–67, https://doi.org/10.1163/15718093-12341416.
[252] General Data Protection Regulation (n 23).
[253] John Rumbold and Barbara K. Pierscionek, "What Are Data? A Categorization of the Data Sensitivity Spectrum," Big Data Research 12 (July 1, 2018): 49–59, https://doi.org/10.1016/j.bdr.2017.11.001.
[254] "The rationale behind regulating particular categories of data in a different way stems from the presumption that misuse of these data could have more severe consequences on the individual's fundamental rights, such as the right to privacy and non-discrimination, than misuse of other, "normal" personal data" in ARTICLE 29 DATA PROTECTION WORKING PARTY, "Advice Paper on Special Categories of Data ('Sensitive Data')," April 2011, https://ec.europa.eu/justice/article-29/documentation/other-document/files/2011/2011_04_20_letter_artwp_mme_le_bail_directive_9546ec_annex1_en.pdf.
[255] Ibid.

encompass information revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, also including genetic data, biometric data for uniquely identifying a person, health-related data, and data concerning a person's sex life or sexual orientation. [256] 'The data related to the brain, despite all the peculiarities and related risks previously highlighted, are not explicitly mentioned within them'.[257]

It is known that information that can reveal a condition of pathological mental status is sensitive data, because it is associated with health data. Article 4(15) of the GDPR defines this type of data as 'personal data related to the physical or mental health of a natural person, including the provision of health care services, which reveal information about his or her health status',[258] being further developed in recital 35 that 'all data pertaining to the health status of a data subject which reveal information relating to the past, current or future physical or mental health status of the data subject'.[259] This definition, generally associated with 'mental health status,' encompasses not just pathological conditions but also the physiological state indicating the absence of mental pathology. Thus, biological parameters typically used to identify mental illnesses qualify as sensitive data even when indicating normal brain function, implying that the concept of mental health should be broadly interpreted to include various cognitive processes and emotional states of an individual.[260] Analysis becomes much more complicated if the information collected does not directly or indirectly reveal non-physiological conditions such as information related to emotions and thoughts, however if these types of data are collected using emotion detection tools that employ biometric methods, like facial recognition technology,[261] a correlation is established with biometric data which is considered sensitive personal data for the GDPR.

So, what we can identify after these considerations is that the regime for considering data as sensitive is too restricted considering current technological advances, and for some authors,[262] data that reveals information about the holder's thoughts is not

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[256] General Data Protection Regulation (n 23).
[257] Sara Latini (n 167), page 38.
[258] General Data Protection Regulation (n 23).
[259] Ibid.
[260] In this path see Giovanni Comandé and Giulia Schneider, "Regulatory Challenges of Data Mining Practices: The Case of the Never-Ending Lifecycles of 'Health Data,'" European Journal of Health Law 25, no. 3 (April 18, 2018): 284–307, https://doi.org/10.1163/15718093-12520368.
[261] Damian Clifford, "Citizen-Consumers in a Personalised Galaxy: Emotion Influenced Decision-Making, a True Path to the Dark Side?," Social Science Research Network, January 1, 2017, https://doi.org/10.2139/ssrn.3037425.
[262] Marcello Ienca and Gianclaudio Malgieri (n 28), page 10.

necessarily sensitive, just because it only refers to the subject's mental sphere, but if we take into account the content, context and purpose of the data processing,[263] it is possible that these types of data could reveal information about the sensitive data[264] contained in Article 9(1) of the GDPR. Considering these insights, it's evident that there is a distinct conceptual and normative gap: despite a public general consensus on the intimate and sensitive nature of mental data, not all such data are safeguarded under the strict provisions of the GDPR for sensitive data. Furthermore, a thorough assessment of the sensitive nature of mental data requires an examination of their inherent qualities and potential, especially when integrated with advanced interpretative methods and technologies. This analysis extends beyond the conventional scope, pushing the boundaries of GDPR's traditional definition of sensitivity to potentially encompass mental data as well, and for this it is necessary to analyse the case C-184/20 of the Court of Justice of the European Union decision that opens the scope of sensitive personal data under the GDPR.

5.4.1. CJEU Case C-184/20 – Concept of Sensitive Data widened *de jure* and *de facto*

The Court of Justice of the European Union case C-184/20 addresses several significant issues related to the processing of personal data under the General Data Protection Regulation, specifically focusing on the concept of sensitive data. The case arose from proceedings between an individual, OT, and the Chief Official Ethics Commission in Lithuania, concerning OT's failure to lodge a declaration of private interests,[265] declaration aimed at fighting corruption and ensuring good government,[266] as administrator of a company that received EU funding, prompting legal proceedings that questioned the intersection of national data processing requirements with the broader scope of the GDPR and the Charter of Fundamental Rights of the European Union. The CJEU's position may be understood as resolving the disagreement between Norway's Data Protection Authority, which advocated for a broad interpretation of "special

[263] Paul Quinn and Gianclaudio Malgieri (n 32).
[264] Stephen Rainey et al. (n 33), page 11.
[265] Judgment of the Court (Grand Chamber), "Vilniaus Apygardos Administracinis Teismas — Lithuania) — OT v Vyriausioji Tarnybinės Etikos Komisija in Case C-184/20," August 2022, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62020CA0184&from=EN.
[266] Aly Marczynski José María Marín, "Compendium of Good Practices on Anti-Corruption for OGP Action Plans," December 18, 2018, https://apo.org.au/node/252866.

categories of personal data" in the Grindr case,[267] and Spain's Data Protection Agency, which conversely determined that no special category of personal data was processed in the identical context.[268]

The disclosure of personal data through declarations of private interests could potentially infringe upon individuals' rights to privacy. Such disclosures might inadvertently reveal sensitive information about a person's living arrangements, sexual orientation, and intimate family and personal relationships. This aspect of the case highlighted the sensitive nature of the data in question and the need for careful legal scrutiny in its handling. At the heart of the CJEU's analysis were two questions for the court to answer and decide: (i) To what extent could the online publication of the TO's declaration of private interests be based on Article 6(1) and (3) of the GDPR as a valid legal basis for data processing;[269] (ii) the publication of the name of the OT partner may or may not be processed in accordance with the limits and conditions set out in Article 9(1) and 9(2)(g) of the GDPR.[270] Restricting the court's good decision to the analysis in this thesis, let's just look at the scope of the second issue.

In addressing the second question, the CJEU's examination centres on data that, while not categorically classified as 'sensitive' under Article 9 of the GDPR, nonetheless carry the potential to disclose sensitive information, like sexual orientation. The Court scrutinized the nature of data specifically related to the spouse, cohabitee, or partner of the declarant.[271] It was noted that such data could inadvertently expose details about the individual's sex life or sexual orientation, as well as that of their partner.[272] To arrive at such sensitive revelations, the Court highlighted the necessity of an "intellectual operation involving comparison or deduction".[273] This process is identified as a key criterion for applying the heightened protection regime, typically reserved for inherently sensitive data, to personal data that are not inherently sensitive but have the potential to reveal sensitive aspects of an individual's private life.

[267] "Grindr Has Appealed the Administrative Fine Imposed by the NO DPA," Datatilsynet, n.d., https://www.datatilsynet.no/en/news/aktuelle-nyheter-2022/datatilsynet-har-mottatt-klage-pa-overtredelsesgebyr-i-grindr-saken/.
[268] "AEPD (Spain) - E/03624/2021," GDPRhub, n.d., https://gdprhub.eu/index.php?title=AEPD_(Spain)_-_E/03624/2021.
[269] JUDGMENT OF THE COURT (Grand Chamber), Case C-184/20 (n 264), [60].
[270] Ibid [117].
[271] Ibid [119].
[272] Ibid [118,119].
[273] Ibid [120].

Unfortunately, the Court does not discuss any further how this “intellectual operation involving comparison or deduction” should be conducted, whether certain criteria should be considered or whether it could be merely – and legitimately – based on stereotypes and common sense.[274] The Court's rationale is primarily based on ensuring consistency in interpreting the provisions related to sensitive data. It also emphasizes the importance of upholding a high standard of data protection, particularly concerning certain facets of private life.[275] This concept of intellectual operation is instrumental in evaluating how data is handled, focusing on whether the processing involves complex mental tasks such as comparing or deducing information from the available data.

The Court takes a contextual approach[276] in its analysis but stops short of detailing the specific criteria for identifying potentially sensitive personal data. Instead of relying solely on this contextual method, the Court could have benefited from a more nuanced approach, incorporating elements of a purpose-based analysis. It would have been pertinent for the Court to acknowledge that the administrative authority in question did not aim, either directly or indirectly, to gather information about the sexual orientation of individuals under transparency obligations. ‘Moreover, the Court does not provide a taxonomy of personal data, either concerning the same data subject or third parties, that combined among them would reveal sensitive information’, undermining legal certainty to data controllers.[277]

As a result of the evolving legal and practical understanding of sensitive data, heightened by advancements on the Internet of Things and increasing interconnectivity, there is a growing likelihood that more personal data will be classified as sensitive.[278]

5.4.2. Expanding Sensitivity to Mental Data

‘If it is possible to indirectly deduce sensitive characteristics about a person from a reading of other personal data, the personal data in question will qualify as special category data – and no amount of risk mitigation measures to that data can remove its

[274] Giacomo Delinavelli, “Comment to Case C-184/20 and the Perils of a Broad Interpretation of Art. 9 GDPR,” European Law Blog, September 21, 2022, https://europeanlawblog.eu/2022/09/21/comment-to-case-c-184-20-and-the-perils-of-a-broad-interpretation-of-art-9-gdpr/.
[275] JUDGMENT OF THE COURT (Grand Chamber), Case C-184/20 (n 264), [125,126].
[276] Ibid [124].
[277] Giacomo Delinavelli (n 273).
[278] Michela Galea, “CJEU Widens the Scope of Sensitive Personal Data under the GDPR,” Data Protection - Worldwide, October 4, 2022, https://www.mondaq.com/data-protection/1236466/cjeu-widens-the-scope-of-sensitive-personal-data-under-the-gdpr.

classification as special category data'.[279] The CJEU's interpretation of the "intellectual operation of comparison or deduction" provides an essential framework for the possibility of extending the concept of sensitive data to cover mental data, and therefore thoughts, suggesting that the process of inferring sensitive information from data involves intellectual operations like comparison or deduction. When applied to thoughts as mental data, this implies that the analysis or processing of such data to infer personal information, such as emotional states, intentions, or preferences, would require a similar level of intellectual operation, involving the possibility to deduce personal characteristics or predispositions from the patterns or nature of an individual's thoughts.

The CJEU's broad interpretation of special categories of data in this judgment establishes a high threshold that, in practice, may prove challenging to effectively manage. Regardless of the rationality of the approach taken by the CJEU, what we can deduce regarding the perception of sensitive data is that it is necessary to analyse whether the data in question can, and we underline can, reveal information related to the sensitive data listed in Article 9(1) of the GDPR by means of an intellectual operation involving comparison, inference, or deduction. Considering the great possibility of mental data being able to reveal the thoughts of each individual with regard to any sensitive personal data contained in the last rule invoked, we can say that, through an intellectual operation where the level of protection of mental data is compared with some sensitive data, the great possibility of their protection being equal to that of sensitive data is inferred and deduced, because otherwise it would result in distinctions being drawn according to the type of sensitive data at issue, thus diminishing the standard of protection which is intended to be afforded to special categories of personal data.

The following question could arise from the possibility of neurotechnology being able to decode thoughts and then realise, if it is possible by advanced technological capabilities for accurately processing and interpreting mental data, that if they can isolate thoughts referring to personal data and sensitive personal data, then we would have thoughts, or mental data, with a sensitive nature and others not? We do not believe that this distinction would be positive for the data subject. Considering the actual complex,

[279] Andre Walter, "EU Court: Data Attributes Revealing Sensitive Personal Data Can Be 'Special Category' Data," Pinsent Masons, August 5, 2022, https://www.pinsentmasons.com/out-law/news/eu-court-data-attributes-sensitive-personal-data-special-category.

dynamic, deeply subjective and fluid nature of thoughts,[280][281] making such a differentiation wouldn't consider the constantly evolving and interweaving connections of thought, so it would complicate even more any attempt to categorize them rigidly. Furthermore, the current state of technology, even with advanced data processing and AI, is not sufficiently developed to distinguish between sensitive and non-sensitive thoughts accurately and reliably, creating a significant risk of misinterpretation and error, which could lead to inappropriate processing of sensitive data.

A challenging scenario also arises as to the legal basis for processing this type of data. Before processing a special category data, controllers must fulfil certain requirements that exceed the standards for processing "ordinary" personal data. This includes identifying a lawful basis as per Article 6 of the GDPR and satisfying an additional condition for processing under Article 9 of the GDPR, but also following specified, explicit and legitimate purposes.[282] When it comes to the "indirect" processing of the special category data, organizations might often need to seek explicit consent from individuals. This necessity arises because explicit consent is frequently the only applicable legal basis under Article 9(2) of the GDPR. The legal bases such as "performance of a contract" or "legitimate interests" apply only under Article 6 of the GDPR for processing personal data. However, in certain situations, organizations may be able to utilize other legal grounds provided in Article 9 of the GDPR. For instance, under Article 9(2)(h) GDPR, processing may be permissible if it is essential for preventive or occupational medicine, medical diagnosis, or for providing health or social care services.[283]

'In case mental data qualify as sensitive data, it is lawful to process them only if one of the lawfulness conditions under article 9(2) of the GDPR can apply, being the explicit, informed and free consent of the data subject the only legal basis for processing these data under a commercial nature',[284] even if obtained under a weak consent regime.[285] The processing of mental data is not limited to commercial purposes; it also encompasses non-commercial scenarios such as medical diagnosis, scientific research, or

[280] John Paul Minda, "The Fluidity of Thought," John Paul Minda, PhD, June 11, 2018, https://jpminda.com/2018/06/11/the-fluidity-of-thought/.
[281] "Fluid Intelligence: Definition, Examples, & Psychology," The Berkeley Well-Being Institute, n.d., https://www.berkeleywellbeing.com/fluid-intelligence.html.
[282] General Data Protection Regulation (n 23), article 5(1)(b).
[283] Ibid.
[284] Marcello Ienca and Gianclaudio Malgieri (n 28), page 11.
[285] Marcello Ienca, Pim Haselager, Ezekiel Emanuel (n 29).

activities in the public interest. For example, when mental data is processed for healthcare purposes, like diagnosis or therapy, article 9(2)(h) of the GDPR permits such processing without the need for specific additional condition.[286] In the context of processing mental data for scientific research, Article 9(2)(j) of the GDPR permits such activities, provided they adhere to specific conditions. This includes the requirement for authorization under a Union or Member State law, ensuring proportionality to the research aim, respecting the right to data protection, and implementing measures to protect the fundamental rights and interests of the data subjects. The appropriateness of such intrusive research, particularly when it delves into the mental sphere of subjects, is subject to scrutiny. However, the European Data Protection Supervisor in a preliminary opinion on scientific research, expressed that behavioural experiments generally fall outside the scope of the research exemption in Article 9(2)(j) of the GDPR.[287] This is because they often lack an established ethical framework to justify their proportionality under the GDPR. In essence, the social and scientific benefits are often outweighed by the potential infringement on the privacy and data protection rights of the research subjects.[288] The applicability of this statement to other research areas involving mental data, which currently may not have a well-established ethical framework to guarantee proportionality, is a subject of discussion. For instance, *Marcello Ienca* points out that there is an argument that areas like cognitive monitoring and self-administered neuromodulation, especially when using non-medical digital mind technologies, may not yet possess a solid ethical framework necessary to ensure their proportionality and justification.[289]

We believe that there are ways that lead to appropriate and safer mental data processing for the data subject, but the solution does not necessarily lie in "multi-layered sensitivity" as has already been proposed,[290] but rather in recognising it as high-risk data that requires specific and tailored Data Protection Impact Assessments. By requiring this assessment prior to processing, DPIAs serve as a proactive measure, helping to identify

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[286] Giulia Schneider, "OUP Accepted Manuscript," International Data Privacy Law, January 1, 2019, https://doi.org/10.1093/idpl/ipz015 in Marcello Ienca and Gianclaudio Malgieri (n 28), page 11.
[287] "Preliminary Opinion on Data Protection and Scientific Research," European Data Protection Supervisor, January 25, 2024, https://edps.europa.eu/data-protection/our-work/publications/opinions/preliminary-opinion-data-protection-and-scientific_en.
[288] Mason Marks, "Artificial Intelligence-Based Suicide Prediction," Scholarship Repository, n.d., https://ir.law.fsu.edu/articles/732/.
[289] Marcello Ienca, Pim Haselager and Ezekiel Emanuel (n 29); Sara Goering and Rafael Yuste, "On the Necessity of Ethical Guidelines for Novel Neurotechnologies," Cell 167, no. 4 (November 1, 2016): 882–85, https://doi.org/10.1016/j.cell.2016.10.029.
[290] Sara Latini (n 167), page 47.

and mitigate risks at an early stage. The DPIA, present in article 35 of the GDPR, involves a thorough assessment and mitigation of data processing impacts, which must be conducted prior to processing and regularly updated as risk levels change.[291] This process is particularly relevant for mental data due to their sensitive nature and significant implications. The advantages of implementing DPIA for thoughts as a form of mental data are substantial. Firstly, it ensures a rigorous evaluation of potential risks associated with processing such thoughts, safeguarding against any undue infringement on privacy and personal freedoms. Secondly, the regular review mandated by DPIAs ensures ongoing vigilance and responsiveness to any changes in risk levels, ensuring that protections remain robust over time. This is particularly important for mental data like thoughts, which may vary in evaluation of sensitivity depending on context and use. Overall, DPIA, or MDPIA,[292] offer a structured and systematic approach to ensuring that the processing of sensitive data, such as thoughts, is handled with the utmost care and respect for individual rights under the GDPR.

CONCLUSION

Concluding on the interplay on the intersection of legal systems with neurotechnology, particularly Brain-Computer Interfaces, it's clear that as we stand on the brink of a new era in human-machine interaction, our legal frameworks must be both reactive and proactive. Thoughts are not just binary or linear; they are multi-dimensional, influenced by a myriad of factors like emotions, context, and subconscious elements. Current BCIs, while making significant strides, still struggle with capturing this multidimensionality. Nevertheless, law must react to these technological advances, ensuring that individuals' rights are preserved even as new forms of data emerge. At the same time, it must proactively promote responsible innovation, guiding neurotechnology development in a direction that enhances societal welfare without compromising personal integrity and 'fundamental aspects of human existence, including mental integrity, human dignity, personal identity, freedom of thought, autonomy, and privacy'.[293]

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[291] Dariusz Kloza et al., "Data Protection Impact Assessments in the European Union: Complementing the New Legal Framework towards a More Robust Protection of Individuals," D.Pia.Lab Policy Brief No. 1/2017, October 9, 2020, https://doi.org/10.31228/osf.io/b68em.

[292] Marcello Ienca and Gianclaudio Malgieri (n 28), page 18.

[293] "Unveiling the Neurotechnology Landscape: Scientific Advancements Innovations and Major Trends," UNESCO, July 20, 2023, https://www.unesco.org/en/articles/unveiling-neurotechnology-landscape-scientific-advancements-innovations-and-major-trends.

The GDPR's robust approach to personal data protection provides a strong foundation, but it may require further specificity when applied to the nuances of these types of data. For instance, how can consent be meaningful when data subjects may not fully grasp the future implications of sharing their brain and mental data? How can privacy be preserved when thoughts and emotions could potentially be decoded and exposed? The answers to these questions lie in a concerted effort by lawmakers, technologists, and ethicists to forge new legal instruments or adapt existing ones to better fit the digital and neural age. This endeavour is not solely about constraining technology but about harnessing its potential responsibly. In the end, the goal of any adaptation in the legal system should be to safeguard the individual's right to cognitive liberty and mental privacy. This means ensuring that people retain control over their own brain and neural data and that they are protected from any form of coercion or discrimination based on that data. It also means fostering an environment where neurotechnology can flourish in a way that is beneficial and ethical, contributing positively to healthcare, education, and beyond.

The CJEU decision discussed in the thesis provides a significant development in data protection law, particularly when it comes to the application of thoughts as mental data. This decision effectively brings thoughts under the umbrella of sensitive data, recognizing their intrinsic value and the need for stringent protection. By interpreting the processing of mental data through the lens of the GDPR, particularly in light of special categories of data, the CJEU has acknowledged that thoughts, as a form of mental data, can reveal sensitive information about an individual. This interpretation aligns with the broader objectives of the GDPR to protect personal integrity and privacy. Consequently, thoughts are not just seen as mere personal data but are given the elevated status of sensitive data, warranting higher standards of protection. This landmark decision by the CJEU marks a pivotal shift in data protection law, ensuring that thoughts, as intimate reflections of the Self, are safeguarded with the utmost care and diligence in line with the GDPR's principles. The significance of this development is further amplified by the role of the Data Protection Impact Assessment as stipulated under the GDPR. The DPIA emerges as a crucial tool in this context, providing a systematic approach to evaluating and mitigating risks associated with processing such sensitive data. It ensures that any processing of thoughts, now recognized as sensitive data, is preceded by a thorough assessment of potential impacts on privacy and fundamental rights. This process not only adheres to the GDPR's rigorous standards but also reinforces the commitment to protecting the nuanced and intimate nature of mental data. Thus, the CJEU decision, in conjunction with the DPIA, represents a comprehensive approach to safeguarding thoughts under the GDPR, highlighting the necessity of robust privacy protections in the evolving landscape of data protection law.

As BCIs bridge the gap between neural activity and the articulation of thoughts, data protection laws, particularly the GDPR, need to evolve in tandem. It is through this informed agility that legal systems can hope to keep pace with the rapid advancements in neurotechnology, providing a framework that not only adapts to but also anticipates the needs and challenges of tomorrow. The GDPR's principles of accuracy, informed consent, and the upholding of data subject rights require careful reinterpretation in this context. It is incumbent upon legal scholars and technologists to collaboratively ensure that as BCIs progress, they do so within a legal framework that maintains the sanctity of personal data and the sovereignty of the individual. This necessitates a legal environment that not only protects but also respects the privacy of our most private cognitive processes.

Given how limited the literature has yet been written on this subject, this thesis aimed at further intensify the debate on possible technological access to data as personal as that which interrelates in the human mind and the proactive need to have applicable legislation that keeps pace with technological development without unexpectedly falling into a reality where we could end up with Mind-Computer Interfaces. 'There are correlations between thinking and brain activities. But all we can conclude is that thinking leaves traces in the brain. Hence, exploring the mind by studying brain states might be like exploring an elephant by studying its footprints'.[294]

Given that the purposes, outcomes, and potential impacts of various data processing activities are similar, we advocate for an expansive approach in data processing activities, one that goes beyond mere categorization of brain or neural data. Our proposal includes a wider spectrum of mental data, not limited to those derived from direct brain activity observation. It also encompasses inferred data about an individual's mental states, whether deduced directly or indirectly, covering the cognitive, affective, and conative states. Such an approach does more than enhance our understanding of the involved data processing, it recognizes the intrinsic and profound nature of our thoughts, acknowledging them as the most sensitive and personal form of data, reflecting the very essence of our being and consciousness. This holistic perspective is vital in shaping data

[294] Bernhard Kutzler, "Thoughts Are Not Products of the Brain - Mind Cafe - Medium," Medium, March 28, 2022, https://medium.com/mind-cafe/thoughts-are-not-products-of-the-brain-a488b6690c99.

protection strategies and guiding our respect for individual privacy and mental integrity. In a technological era where the distinction between external data and internal thought processes becomes increasingly blurred, it is imperative to consider the full spectrum of implications. Our approach must evolve to address the nuanced challenges posed by such advancements, involving not only crafting policies that protect personal mental data, but also fostering a societal understanding that recognizes and respects the sanctity of our inner mental world, ensuring that as technology advances, it does so with a keen awareness of the ethical and personal boundaries it navigates, so that what we've seen in the science fiction cinematic world doesn't become our reality.

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