Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 5025-5040
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.3106

Legal and economic assessment of Neuralink: Between today's challenges and future aspirations analytical descriptive study

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Abstract: This research explores the legal and economic challenges associated with Neuralink's innovative technology that merges artificial intelligence with the human brain. This technology allows individuals to control devices with their thoughts and addresses neurological disorders, thereby enhancing human capabilities. Legal concerns focus on privacy issues arising from brain data collection, necessitating new laws to protect individual rights. Questions of liability for damages also arise, determining whether responsibility lies with Neuralink or the users. Additionally, the ethical implications of enhancing human abilities and their effects on identity are examined. Economically, Neuralink could drive innovation, increase productivity, and create specialized jobs while transforming the labor market. It holds promise for improving healthcare and education, thus enhancing overall quality of life. It highlights that protecting rights is vital for innovation and meeting societal needs. It emphasizes safeguarding individual rights to promote innovation and ensure technology benefits society.

Keywords: *Brain computer interface (BCI), Brain machine interface, Informed consent, Privacy, Social and economic impacts- AI.*

1. Introduction

Background: Brain-Computer Interfaces (BCIs) like Neuralink technology are innovative systems enabling direct communication between the brain and computers by translating neural signals into device commands, with promising applications in medicine, particularly for individuals with disabilities (Lebedev & Nicolelis, 2006); (Maiseli et al., 2023). Neuralink, founded by Elon Musk, is a pioneer in this field, aiming to create implantable chips for enhanced brain-device interaction. Notably, experiments have demonstrated a monkey controlling video games solely through brain activity. The company plans to initiate human clinical trials, potentially transforming human-technology interaction. Neuralink represents a significant advancement in integrating artificial intelligence with human capabilities, seeking to improve cognitive functions and experiences through brain-computer connectivity (Athanasios Drigas & Angeliki Sideraki, 2024). However, these advancements prompt critical legal considerations. Key challenges include protecting individuals' rights regarding sensitive brain data, emphasizing the need for robust privacy and security legislation Rayhan, S. (2023). Questions about liability for potential damages—whether the manufacturer or user is responsible—highlight the necessity for clear legal frameworks. Additionally, Neuralink raises ethical concerns about modifying human capabilities (Drew, 2019) and its implications for identity and human rights. As technology evolves, it's crucial to establish adaptable regulations that prioritize individual rights, ensuring responsible economic and social growth.

2. Objectives of the Research

Analyze the legal challenges associated with Neuralink' s technique, including privacy and security issues, Explore Neuralink' s economic impacts on markets and employment, make

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recommendations for laws that could effectively regulate this technology.

2.1. Questions of the Research

These questions will guide the research and help achieve its set goals as follows:

-What are the main legal challenges facing Neuralink technology?

-How can Neuralink technology affect the global economy?

-Based on the description and analysis of the current legal gaps we offer proposals to regulate Neuralink technology.

3. Research Methodology

Reviewing studies and articles on this technique and describing the technology's legislative gaps. With a focus on the legal and economic dimensions of Neuralink' S technology, taking into account current challenges and future aspirations. The methodology will include the description and analysis of available literature, including legal influences such as privacy protection and legal liability, as well as economic aspects such as potential returns and necessary investments.

3.1. Previous Studies

The article entitled The Potential Pitfalls of Technologies like Elon Musk's Neuralink, 2020) examines the legal and ethical implications of technologies Jus Corpus. (2023)like Neuralink. It highlights challenges in assessing criminal responsibility, ethical concerns regarding neurological interventions and privacy, and issues of unequal access. The study also points out potential health risks and the effects of these technologies on human interaction.

Several companies are testing brain implants – why is there so much attention swirling around Neuralink" (Ko, A., & Jecker, N. S. (2024) The article by University of Washington professors discusses the ethical and legal challenges associated with Neuralink technology, focusing on privacy and social inequality concerns. It notes the device's capabilities in neuron targeting and brain activity monitoring, along with its FDA approval for human trials set for January 2024. The article emphasizes Neuralink's potential to help individuals with motor impairments control devices through thought as a critical topic in neuroscience safety and ethics.

The article entitled Ethical Considerations of Neuralink and Brain-Computer Interfaces: This Springer paper explores the ethical considerations of neural interfaces, focusing on their societal impacts and risks while promoting responsible innovation. It highlights key issues such as the ethical challenges of brain-computer interfaces, the need for patient awareness regarding risks, concerns about battery safety and device removal, and the potential medical advancements alongside related legal and ethical challenges. Waisberg, E., Ong, J., & Lee, A. G. (2024).

Study entitled the legal implication of Neuralink and brain-interfaced technologies*:* The paper examines the legal and ethical issues arising from advancements in Neuralink and similar brain technologies, with a focus on privacy, data protection, and individual autonomy. It emphasizes the necessity for updated legal frameworks to tackle these challenges and discusses the implications for intellectual property rights and liability concerning potential harm or errors. Bublitz, C., Wolkenstein, A., Jox, R. J., & Friedrich, O. (2019). By reviewing previous studies, we can demonstrate the connections between these studies, and the research topic that evaluates the legal frameworks, and economic consequences of Neuralink technologies, which are pioneering innovations in brain-computer interfaces.

4. Legal Challenges

4.1. Assessment of Civil and Criminal Liability for Brain Interface Technologies, including Computer and Neuralink Technology

Recent advancements in brain-computer interfaces (BCI) and Neuralink have improved human-machine communication, creating new possibilities in medicine, (Purvish Mahendra Parikh & Ajit Venniyoor, 2024) education, and entertainment. However, they also pose complex legal and ethical

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5025-5040, 2024
DOI: 10.55214/25768484.v8i6.3106

challenges, especially regarding civil and criminal liability. Civil liability relates to compensation for damage that may be caused to individuals or property as a result of the use of these techniques. (Thompson, 2019) When a user is harmed by the use of BCI technology, questions arise as to who bears responsibility, whether that's the manufacturer, the developer, or even the user himself. It requires careful assessment of multiple factors, including technology design, approved use, and potential impact on individuals. On the other hand, criminal liability relates to the determination of the criminal acts that may occur as a result of the use of this technique, and who is responsible for it. BCI techniques Neuro, V. (2024) may cause unlawful acts, such as manipulating the mind or controlling individuals' behavior, further complicating legal matters. Here, it is important to consider the actor's intention and the extent to which the technology influences its decisions, which raises questions about the extent to which individuals or companies can be held accountable for acts that may result from the use of these technologies. Kemper, C. (2020).In this context, it may become necessary to explore both types of responsibility more deeply, to understand the legal and ethical challenges associated with brain-computer interface techniques.

4.2. Civil liability for Damages Resulting from Brain-Computer Interface Technologies and Neuralink Technology

BCI like Neuralink technologies are characterized by great complexity, as civil liability relates to compensation for damages that may result from using these technologies, in this software, hardware, and neural data overlap. This complexity makes it difficult to determine the exact source of any error or damage, for example, if a user is exposed to damage using BCI technology, (Burwell et al., 2017) or a person being harmed as a result of a defect in a device that uses Neuralink technology. It may be difficult to determine whether the error results from the design of the device, software, negligence, manufacturing error, or even user misuse. These technologies involve many parties involved, including manufacturers, developers, and users. In the event of damage, the responsibilities of those parties may overlap, and the question is whether the developer bears responsibility for the software used in those technologies, or is the manufacturer responsible for the device. Likewise, in many cases, it may be difficult to prove the causal relationship between the use of technology and the resulting harm. For example, if a person is exposed to psychological harm after using these technologies, it will not be easy to prove that the technology is the direct cause of this harm, especially if factors intersect. Others contributed to this. It requires strong evidence to prove that the damage was a direct result of the use of technology. Khan, S., Cole, D., & Ekbia, H. (2024). Certainly, this overlap in responsibilities increases the complexity of technical matters, which may require a re-evaluation of traditional concepts of liability, such as the concept of negligence, as it may be difficult to prove that the user or company has acted irresponsibly in the context of using these technologies. Civil liability in Neuralink technologies is still in its infancy. It is a vital area that requires further legal research and development. It will be necessary for legal and legislative authorities to cooperate with technical experts to ensure the establishment of effective legal frameworks that protect individuals and ensure fair compensation. For those affected, which contributes to strengthening confidence in these technical innovations.

4.3. Criminal Liability

As the study "The Potential Pitfalls of Technologies like Elon Musk's Neuralink" (2020) demonstrates, establishing criminal liability for crimes committed using brain-computer interfaces is a major legal challenge. Legal systems require the development of new frameworks for determining liability in such cases. By analyzing the problem of criminal liability in the context of the use of Neuralink techniques, several aspects should be taken into account, inter alia:

4.3.1. The Concept of Voluntary act:

In traditional criminal law, involuntary act is a prerequisite for liability, but if Neuralink techniques and brain-computer interfaces are used, it is difficult to determine whether the act was done at the user's will or as a result of the impact of the technique. This requires a reassessment of

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ISSN: 2576-8484
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the concept of the will in technical contexts.

4.3.2. Actor Ambiguity:

When dealing with Neuralink techniques and brain-computer interface (BCI) it may be difficult to identify the real actor in the case of a crime. Is the actor the user who operated the technology, the developer who created the software, or the company that made the device? This ambiguity in determining the actor complicates the legal accounting process of any of the parties involved. In some cases, the actor may be completely unknown, further complicating legal matters and making it difficult to apply justice effectively.

4.3.3. Human-machine overlap:

BCI technologies like Neuralink technology integrate human capabilities with machines, leading to overlap in responsibilities. (Maiseli, B, et al., 2023) In the case of a crime, it may be difficult to determine whether a person's decisions have been significantly influenced by the technique, raising questions about the freedom of individual will. If a person behaves in an unusual manner as a result of the influence of the technique, it may be difficult to hold him accountable for his actions.

4.3.4. Difficulty in proving criminal intent:

Criminal liability typically requires proof of criminal intent, which can be challenging in the context of the use of brain-computer interface (BCI) and Neuralink technologies. When a person commits a crime while using this technology, it can be difficult to prove that they had a clear intention to commit the crime, especially if the technology affected their behavior in unexpected ways. This requires strong evidence to prove that the person was aware of the consequences of his or her actions, further complicating legal issues regarding criminal intent.

5. Shared Responsibility in Brain-Computer Interface Technologies Like Neuralink

In some cases, there is an overlap between the responsibilities that companies and users have, when using brain-computer interface (BCI) technologies. For example, if a user uses this technology in illegal ways, while the technology itself suffers from security flaws, three proposed theories have emerged to deal with this problem: (Bublitz et al., 2019)

5.1. Developing company

Companies that develop brain-computer interface (BCI) technologies are likely to be held liable if their technology is unsafe or is used in unexpected ways. Therefore, it is necessary to establish clear criteria to evaluate the safety of these technologies, which calls for careful and comprehensive testing before products are put on the market.

5.2. Manufacturer

If problems arise with the manufacturing process, the manufacturer may be held liable for resulting damages. This requires legal mechanisms that allow users to sue companies in the event of damages caused by defects in the product

5.3. User Itself

The user may also bear part of the liability, if he uses the technology illegally or irresponsibly. This raises questions about how users are made aware of their legal, ethical responsibilities (Chandler, J. A 2,022) when using these technologies, and it can be argued that there is a shared responsibility between the parties. This situation calls for the need to develop effective legal mechanisms that allow for a fair division of responsibility among all parties. This situation calls for the need to develop effective legal mechanisms that allow for a fair division of responsibility among all parties concerned, thereby contributing to the achievement of justice and the protection of individuals' rights.

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ISSN: 2576-8484
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5.4. Unexpected Effects

Brain-computer interface (BCI) techniques can lead to unexpected effects of users' behavior, King, B. J., Read, G. J., & Salmon, P. M. (2024). Complicating the process of determining responsibility. If the user behaves in unusual ways as a result of the impact of this technology, it can become difficult to hold him accountable for his actions. This further complicates the determination of criminal responsibility, where the impact of the technique overlaps with an individual's ability to make informed decisions

6. Analysis of Privacy and data Protection Problems

Neuralink technology requires the collection of sensitive data from the brain, raising questions about how this data is protected. Hurley, D. (2024). Furthermore, such brain-derived data may be compromised or unauthorized, requiring clear mechanisms. To compensate individuals for damages resulting from violating their privacy or data leakage

6.1. Rights Related to Neuralink Brain-Computer Interface Technologies

Such as Neuralink, raise the right to mental privacy, cognitive freedom, mental integrity, and psychological continuity as fundamental rights Jawad, A. J. (2021), Botes, M. W. M. (2022).

6.1.1. The Right to Mental Privacy

The right to mental privacy is one of the fundamental rights that may be at risk when using brain-computer interface technologies. This technology is capable of reading and analyzing mental activities, which raises concerns about the possibility of leaking personal information or private thoughts. Mecacci, G., & Haselager, P. (2019). Therefore, it is necessary to establish clear legislation to protect individuals from any violation of their mental privacy, and to ensure that brain-extracted data is used in an ethical manner and with informed consent.

6.1.2. The right to mental integrity:

The right to mental integrity refers to the need to protect individuals from psychological harm that may result from the use of brain-computer interface technologies. Uninformed experiments or improper use of this technology may lead to negative effects on mental health. Hildt, E. (2022), Douglas, T., & Forsberg, L. (2021) Therefore, legal frameworks must include strict standards to ensure the safety of users, including psychological risk assessment before using these technologies.

6.1.3. The right to psychological continuity:

The right to psychological continuity concerns the ability of individuals to maintain their psychological identity and personal history. As brain-computer interface technologies develop, this identity may be compromised if thoughts or memories are unauthorized, SANDUA, D. (2024) altered or modified. Therefore, there must be legal safeguards that protect individuals from any unwanted interference in their psychological experience, ensuring that their personal identity remains preserved. Clear legislation must be put in place to protect the rights of individuals and ensure that their data is not used illegally or harmfully.

6.1.4. Ethical and social concerns:

Neuralink technology raises ethical and legal issues related to the integration of technology with humans, which may modify human capabilities. How can the use of such technologies be regulated to ensure that ethical or legal limits are not exceeded in modifying human identity?

7. The Impact of Neuralink Technology on Human Identity

Human identity is one of the fundamental issues raised by Neuralink technology. When a person's mental or physical abilities are modified, the concept of identity may change radically. This modification may lead to the loss of basic human characteristics, Garbe, T. (2024) such as independent thinking, creativity, and personal experiences. There is concern that individuals will

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ISSN: 2576-8484
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become more dependent on technology, which may impair their ability to make decisions for themselves, and affect the nature of human relationships

7.1. Ethical Issues Related to Control

There are concerns that Neuralink technology may be used to control individuals in unethical ways. (Seth, A., & Gordon, E. C, 2024) If there is a possibility of manipulating thoughts or feelings, this raises questions about personal freedom. Will individuals still be able to make their own decisions freely, or will they become vulnerable to outside influences? This type of control can lead to serious human rights violations.

7.2., The Impact of Technology on Mental Health

Neuralink technology may also impact individuals' mental health. Relying on technology to improve mental abilities may lead to anxiety and depression, Seth, A., & Gordon, E. C, 2024) especially if it does not achieve the desired results. There is also concern that individuals may feel pressured to adopt this technology in order to compete in society, which may lead to feelings of isolation or inadequacy.

7.3. Definition of Informed Consent:

Informed consent refers to the process that ensures that individuals are fully aware of the risks and benefits associated with medical or research procedures before deciding to participate. An alternative procedure may also be recommended, Mohamed, O. I., Khedr, R. I., Ali, H. M., & Abdelaziz, S. A. M. (2024) or it may amount to a refusal of the medical procedure. This requires healthcare providers to provide clear and comprehensive information about the procedure, enabling patients to make informed decisions.

7.4. Analysis of the Challenges of Informed Consent

Informed consent is a cornerstone of medical ethics, especially in areas such as BCI, and Neuralink technologies that seek to integrate the brain with a computer. As this technology develops, it becomes essential to understand how to effectively apply informed consent to ensure that the rights of patients and research participants are protected.

7.8. Applying Informed Consent in Neuralink Technologies

When studying technologies such as Neuralink, which involve implanting chips in the brain, it is necessary to carefully explain the risks and benefits. This technology represents a major advance in the medical field, Musk, E. (2019). But it may carry risks such as infection, psychological effects, or changes in neurological function. Therefore, clinical trial participants must have a comprehensive understanding of what the procedure involves.

8. Challenges Associated with Informed Consent in Neuralink Technologies

The informed consent process in the context of Neuralink faces several challenges, George, A. S. (2024) including, Technology-related information may be complex, making it difficult for patients to fully understand. Patients may feel pressured to agree to participate because of the hope of a cure or improvement. As research progresses, risks, and benefits may change rapidly, which requires updating information provided to participants. It is therefore essential that there is an ongoing dialogue between doctors and patients to ensure that the information provided remains accurate and up-to-date. This communication helps build trust and enhances patients' ability to make informed decisions.

8.1. Social Impacts:

Neuralink technology may lead to social discrimination between individuals. If this technology is only available to the wealthy, the gap between social classes may widen. Individuals who have access to

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ISSN: 2576-8484
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these technologies may enjoy enhanced capabilities, giving them a competitive advantage over others. Garbe, T. (2024) this can create a divided society, where some have superior abilities while others remain in a lesser position. Ethical and technical challenges can affect market acceptance of these technologies, affecting the economics associated with their adoption and development.

9. Economic Challenges of Neuralink Technology

Neuralink technology, represents one of the most ambitious innovations of modern times. (Basri, T, 2025) However, this technology faces a set of economic challenges that may hinder its progress and spread. I will review them as follows:

9.1. High Development Costs

Developing advanced neural interfaces requires huge investments in research and development. These costs include hardware design, software development, and conducting clinical trials. These high expenses may result in delays in bringing products to market, negatively impacting potential returns. The need for continuous financing may also put pressure on investors, which may result in them being reluctant to support the project.

9.2. Lack of Specialized Competencies:

Neuralink technology requires advanced skills in multiple fields, such as neural engineering, neuroscience, and artificial intelligence. This lack of expertise can slow down the development process and increase costs, as companies may have to pay high salaries to attract the necessary talent. Additionally, it can be difficult for startups to compete with larger organizations that have the resources to hire top talent

9.3. Necessary Infrastructure

Neuralink technology needs advanced infrastructure to support its operations, including fast and reliable communications networks. The lack of this infrastructure in some areas may limit the potential for widespread application of the technology, affecting potential returns. Developing this infrastructure also requires additional investments, which increases the financial burden on the company

9.4. Market Competition

Neuralink faces intense competition from other companies in the same industry, which could put pressure on prices and reduce potential profits. This competition may affect Neuralink's ability to attract the necessary investments, as investors may prefer to support other companies with better market opportunities. In addition, new innovations from competitors may reduce Neuralink's market share

9.5. Market Expectations and Public Acceptance

There may be hesitation by consumers to adopt this technology due to safety and privacy concerns. Lynn, D. J. (2024) If Neuralink cannot build trust with the public, it may have difficulty achieving its business goals. It is important for the company to improve communication with the public and effectively explain the benefits of technology.

9.6. Evaluation of Current National and International Legal Frameworks for Neuralink Technology Challenges

In Egypt, legislation regarding artificial intelligence technology and brain-computer interface technology, Neuralink technology, is still pending. Far from keeping pace with this technology directly, however, there are some laws and procedures that can address certain aspects of these technologies:

9.6.1. Telecommunications Regulatory Law (Law No. 10 of 2003)

This law focuses on regulating telecommunications services and digital data management, which is an essential element in the processes of artificial intelligence and BCI. The law aims to ensure safe and efficient use of telecommunications infrastructure, which contributes to supporting innovation in the field of Neurotechnology.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5025-5040, 2024
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9.6.2. Law No. 175 of 2018 Regarding Combating Information Technology Crimes, Egypt, WIPO Lex, 2018

It aims to regulate the use of technology and protect data. However, these laws may not be sufficient to cover all aspects related to Neuralink technology, especially with regard to privacy and security.

9.6.3. Personal Data Protection Law (Law No. 151 of 2020)

This law sets strict standards for the protection and security of personal data, which directly affects systems containing huge amounts of neural data. The law requires explicit consent from the individuals before their data is collected or used, and guarantees their right to request that their data be deleted from the systems used.

9.6.4. National Strategy for Artificial Intelligence 2021 (Ministry of Communications and Information Technology, 2024)

Egypt launched the National Strategy for (Artificial Intelligence in July 2021) , which aims to establish regulatory frameworks for the ethical and responsible use of artificial intelligence technologies in Egyptian society. The strategy includes developing policies that support innovation and protect individuals' rights at the same time

9.6.5. Egyptian Charter for Responsible Artificial Intelligence (NCAI, 2021)

This charter was launched in April 2023, and aims to crystallize regulatory frameworks for the ethical and responsible use of artificial intelligence technologies. The Charter helps ensure that AI systems are managed, developed and deployed consciously and responsibly, strengthening confidence in these technologies.

10. Analyzing the Legal Gaps in Egyptian Legislation related to Neuralink Technology Neural Data Protection

Egyptian legislation lacks legal texts specifically for the protection of neural data. The Personal Data Protection Act 2020 focuses on traditional data, leaving neurodata without adequate protection, which may raise concerns of unauthorized access and hacking. If these technologies develop and are widely used in countries one day, then legislators in Egypt must begin to take into account the development of new laws to confront the challenges posed by these advanced technologies.

10.1. Criminal Liability

When assessing criminal liability related to the use of brain-computer interfaces, (McCay, 2019) there is an absence of clear legal frameworks around this. Current laws do not include scenarios in which this technology could be used for criminal purposes, raising questions about who bears responsibility when harm occurs as a result of the use, Robb, L., & Kiel-Chisholm, S. (2024)) whether it is the developer, manufacturer, or user. Therefore, there is a need to develop a legal framework that accurately defines the responsibilities and obligations of all parties involved, especially with the growing recognition that these technologies represent a part of human identity.

10.2. Commitment to Inform (Informed Consent)

Current laws center around informed consent for traditional medical procedures, which is disproportionate to the risks and benefits of Neuralink technology. With the potential for success of this technology, companies are expected to commit to providing comprehensive information to users, ensuring they fully understand the use of this technology, including potential side effects and health risks. (Ian, 2024)

10.3. Neurological Manipulation

Due to the novelty of the technique presented in this research, there is no specific legislation that addresses manipulating the neural activity of individuals in illegal or unethical ways. (Ian, 2024) Current laws do not adequately cover situations in which individuals' neural activity can be manipulated

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10.4. Intellectual Property

Current legal frameworks lack clear provisions defining intellectual property rights for ideas and innovations developed using brain-computer interfaces. Current laws regarding intellectual property do not cover neural data and thoughts recorded by the devices. (The White House, 2024), (Pallone, 2022).

11. Analysis of the Legal Gaps in US Legislation Related to Neuralink technology

11.1. Neural data Protection

Current US laws, such as the Health Privacy Protection Act (HIPAA), point to a focus on traditional health data, but do not include neural data generated by devices such as Neuralink. This deficiency opens the way for unauthorized or unethical use of this data. Moreover, this legislation does not cover important issues such as criminal liability, informed consent, neural manipulation, and intellectual property rights, which requires updating it to meet new needs.

Harmonized regulatory framework for brain-computer interfaces (BCI) Musk, E. (2019) technology in the European Union In light of the rapid development of brain-computer interfaces (BCI) technology, which appeared in 1998, scientists implanted electrodes in the brains of two patients to enable them to control a computer using their thoughts, while Neuralink was founded in 2016 to develop advanced technologies for implanting electrodes in the brain. To enable direct communication between the brain and electronic devices, Shaima, M., et al, Q. (2024)

and the European Union seeks to establish a unified regulatory framework that ensures the protection of individuals' rights and the safety of using this technology. These efforts include several main axes

11.2. Neural Data Protection Under GDPR

The General Data Protection Regulation (GDPR) imposes strict requirements on the processing of neuronal data, including its collection, storage, and use. However, the EU should issue additional directives related to neural data due to its extreme sensitivity, to better ensure that individuals' privacy is protected.)Parliamentary Assembly of the Council of Europe, 2013(

Developing unified regulatory directives: The European Union is working on drafting uniform regulatory directives for BCI, aiming to harmonize standards among member states. Botes, M. W. M. (2022)These directives will ensure the safety and effectiveness of the devices used, and specify the procedures necessary to obtain the required licenses and permits. Cooperation between member states: The European Union encourages enhanced cooperation between Member States to exchange experiences and best practices in the field of regulating BCI.)Regulating the Future: Navigating Ethical and Legal Pathways in Brain-Computer Interface Technology ,2024) This cooperation includes developing ethical guidelines and laws regulating the use of this technology in the medical field, to ensure the protection of patients' rights. Supporting research and studies: The European Union supports research and studies aimed at assessing the economic and social impacts of BCI. Botes, M. W. M. (2022)) these studies help develop effective policies to deal with potential impacts, and ensure that technology is used in safe and ethical ways.

The role of European institutions: such as the European Parliament and the European Commission, play a key role in developing the common regulatory framework. (The Neurorights Foundation, 2024) These institutions draft legislation and directives that Member States are obligated to implement, to ensure effective and safe regulation of BCI. These points represent efforts by the European Union to develop a unified regulatory framework for brain-computer interface technology, enhancing protection and unifying standards among member states. Analysis of the legal gaps for dealing with Neuralink technology in the European Union: Despite the implementation of the GDPR, specific guidance is needed to protect sensitive neuronal data. Also, there is no clear legal framework for criminal liabilities in the event of errors or damages resulting from the use of Neuralink technology, which requires the development of laws that define responsibilities between manufacturers, users, and medical practitioners. Neuralink technology may be used to manipulate thoughts or behaviors in unethical ways, so strict laws and oversight mechanisms are needed. The protection of intellectual property rights

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Vol. 8, No. 6: 5025-5040, 2024
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related to Neuralink technologies also needs to be strengthened using patent, copyright, and trademark laws. There is a lack of clear regulatory standards and licensing procedures for Neuralink technology, which calls for the development of a unified regulatory framework for BCI in the European Union. The use of Neuralink technology in medical applications raises ethical issues related to clinical trials and informed consent, requiring the development of ethical guidelines and laws. Finally, the impact of Neuralink technology on the labor market and the economy requires economic assessments and studies to identify potential impacts and develop policies to deal with them. These gaps need to be addressed to ensure effective and safe regulation of Neuralink technology in the EU.

Analysis of the legal gaps for Neuralink technology in France: The absence of clear guidelines for protecting sensitive data despite the existence of the General Data Protection Regulation (GDPR). (Chen, Y et al., 2024) It also points out the lack of a legal framework that defines criminal responsibilities related to the use of Neuralink technology, and a lack of laws to prevent misuse in manipulating thoughts and behaviors. In addition to the weak protection of intellectual property rights and the absence of regulatory standards for brain-computer interface technologies. The lack of ethical guidelines and laws in the medical field also leads to a lack of legal and economic studies that evaluate the impact of this technology on the labor market and the economy. (Kubben, 2024), (Lazarou, I, et al., 2018) Legal gaps in legislation in Italy for Neuralink technology .The need to develop specific directives for neural data protection in Italy, where the General Data Protection Regulation (GDPR) applies the same as in France (Greenberg, J., 2021). Special guidelines are essential for protecting sensitive neuronal data and addressing issues related to criminal liability, intellectual property, regulation, and medical ethics, (Burwell et al., 2017) while also considering the economic and social impacts of these technologies. (Binkley, C. E., et al., 2021) Chile: There are legal gaps related to the regulation of this technology, including the protection of personal neural data, criminal liability, and medical ethics, (Parliamentary Assembly of the Council of Europe, 2013(in addition to regulation, licensing, and economic and social impacts. The importance of developing a comprehensive legal framework is emphasized by governments, and legislators to keep pace with these rapid developments and ensure effective and safe regulation of Neuralink technology. After analyzing the legal gaps that face major challenges in dealing with Neuralink technology, we move on to research its economic impact.

12. Evaluating the Economic Impacts of Neuralink Technology

Significant changes are expected in the economy, as Neuralink technology may lead to the replacement of some traditional jobs and new jobs that require advanced Neurotechnology skills. It can also enhance productivity and improve the quality of life of individuals with disabilities, (Pothireddy, 2023) However, governments need to develop economic and social policies to ensure that benefits are distributed fairly and inequality is avoided. In addition, there is a need to develop integrated legislation that takes into account the unique characteristics of Neuralink technology to ensure its safe and ethical use

12.1. The Impact of Neuralink Technology on the Labor Market

Neuralink technology is considered a revolutionary innovation that could radically transform the labor market. This technology is expected to bring about significant changes in the nature of jobs and skills required, necessitating a comprehensive study of its economic impacts. This technology can lead to the following:

1- Replacing some traditional jobs with new one, that require advanced skills in Neurotechnology For example, there may become an increasing need for specialists in programming and maintaining neural devices, creating new job opportunities in this field. (FitzGerald, 2023)

2-Neuralink technology is expected to contribute to increasing productivity by improving the mental and physical capabilities of individuals. Which leads to improved job performance and increased efficiency in many industries. (Bonaci et al., 2014)

3- Neuralink technology may help individuals with physical or neurological disabilities return to the labor market, which enhances the inclusiveness of the workforce and reduces unemployment rates among these groups. (FitzGerald, 2023), Musk's Neuralink, 2023)

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Vol. 8, No. 6: 5025-5040, 2024
DOI: 10.55214/25768484.v8i6.3106

12.2. Social and Economic Challenges

Despite the potential benefits, Neuralink technology may face social and economic challenges. Increased reliance on technology may lead to economic disparities between individuals who have access to this technology and those who cannot. Therefore, governments must develop policies to ensure that benefits are distributed fairly and to prevent economic and social inequality. (United Nations.2019). Emphasizes the importance of providing training and rehabilitation programs for workers to help them adapt to the changes resulting from Neuralink technology. This helps bridge the gap between skills needed and available in the labor market. Dealing with the effects of this technology also requires developing economic and social policies that take into account the expected transformations to ensure that the benefits are distributed fairly and sustainably. (Julian Florkey.2023), (United Nations. 2019).

12.3. Health Costs of Neuralink Technology

Neuralink technology could revolutionize healthcare, but its implementation necessitates complex brain surgeries that raise health costs significantly. This creates challenges for health systems, especially in resource-limited areas, due to the requirements for specialized medical teams and advanced equipment. To ensure sustainable healthcare, it's crucial to assess the economic implications, as patients will need ongoing follow-up care for device management, leading to increased long-term expenses.

Neuralink technology is characterized by its advanced and expensive neural hardware and software, creating notable challenges for health systems, especially in low-resource settings. Its high costs could result in changes to health insurance policies and increased premiums. This raises ethical and economic issues, prompting the need for governments and health institutions to implement policies that ensure equitable benefit distribution and effective cost management. Therefore, comprehensive health and economic policies are essential for ensuring sustainable access to this technology. (Chaudhary, P & Agrawal, 2018)

Neuralink technology not only enhances human capabilities but also drives industrial innovation and economic growth. It can create new industries, (Julian Florkin, 2023) such as brain-interfacing devices and advanced software, attracting significant investment in research and development. By boosting individuals' mental and physical abilities, Neuralink can improve worker efficiency and productivity, further contributing to overall economic growth (Musk's Neuralink, 2023)

12.4. Long-Term Economic Impacts of Neuralink Technology

Costs associated with research and development, Neuralink technology requires huge investments in R&D to develop advanced neural hardware and software. These costs include salaries for scientists and engineers, equipment costs, and clinical trials. • As technology evolves, there will be a constant need to update hardware and software to ensure optimal performance and safety.

Table 1.
Spending on research and development and the number of workers in research and development in the United States of America and France during the period (2010-2020).

Country	USA		France	
Year	Percentage of spending on research and development as a percentage of GDP	Number of R&D workers per million people	Percentage of spending on research and development as a percentage of GDP	Number of R&D workers per million people
2010	2.71	3549	2.18	3911
2011	2.74	3664	2.19	3981
2012	2.67	3650	2.23	4114
2013	2.70	3736	2.24	4200
2014	2.72	3837	2.28	4282
2015	2.79	3875	2.23	4386

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5025-5040, 2024
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2016	2.85	3830	2.22	4467
2017	2.90	3959	2.20	4625
2018	3.01	4262	2.20	4757
2019	3.17	4309	2.19	4870
2020	3.47	4452	2.28	4986

The table shows an increase in the percentage of spending on research and development in the United States from 2.71% to 3.47%, an increase estimated at 0.76% during the period (2010-2020), but that percentage increased in France from 2.18% to 2.28%, an increase estimated at only 0.1% during the period (2010-2020). The same period, which indicates the interest of the United States in steadily increasing spending on research and development, and the modest increase in spending on research and development in France during the same period, and the number of workers also increased. In the field of research and development per million people in the United States from 3,549 to 4,452 people during the same period, the number of workers in the field of research and development per million people in France also increased from 3,911 to 4,986 during the same period, as the number of workers in research and development increased by about 25%. In the United States of America during that period, the number of workers in research and development increased by about 27% in France in the same period, which indicates the interest of both countries in the field of research and development, and then the steady increase in the number of workers in research. And development. A study confirms the importance of strengthening the research and development sector and improving the quality of education to produce innovative technologies that contribute to achieving sustainable development.

12.5. Organizational costs

Neuralink must adhere to various health and regulatory laws across countries, necessitating extra investments in legal consulting. Additionally, clinical trials and regulatory approvals (COMPUTERS & LAW, 2024.) demand considerable time and resources to verify the technology's safety and effectiveness before market launch

Potential economic benefits: Neuralink technology can enhance workers' mental and physical capabilities, boosting productivity and economic growth. It may also create new industries and jobs, while improving quality of life and reducing health costs. The initial costs of adopting Neuralink technology may be high, which may be a barrier for SMEs. Neuralink technology presents ethical concerns regarding privacy and data control, necessitating strict protective policies. Waisberg, E., Ong, J., & Lee, A. G. (2024). While it has the potential for long-term economic benefits by boosting productivity and creating new industries, it requires substantial investments in R&D and regulatory compliance. Additionally, there are notable differences in the legal and economic frameworks governing Neuralink technology between the U.S. and the EU.

In the U.S., legal frameworks prioritize individual rights and information privacy, with laws like HIPAA governing health information. However, there is no specific legislation addressing Neuralink technology, highlighting the urgent need for new laws to protect individuals' rights in this context. The European Union has robust legal frameworks like the General Data Protection Regulation (GDPR), (Wolford, B, 2024), (European Commission, 2021) which mandates strict personal data protection standards for Neuralink technology. Compliance with these laws enhances privacy and individual rights while reflecting a strong interest in medical ethics and responsible technology use. The U.S. is an open market fostering innovation but faces challenges related to the high costs of developing and maintaining technologies like Neuralink. Economic strategies are needed to support innovation and access. while The EU balances innovation with individual rights, supporting research through funding while considering the social and economic impacts of Neuralink, such as effects on the labor market and benefit distribution. The legal and economic frameworks for Neuralink technology vary between the U.S. and the EU. The U.S. prioritizes innovation and new legislation, while the EU balances individual rights with innovation through comprehensive regulations

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5025-5040, 2024
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12.6. Potential Social Impacts

Neuralink could significantly alter human interaction by reducing reliance on verbal communication, potentially leading to: Diminished importance of social skills and relationships. Increased isolation for those lacking access or preferring traditional communication. Dramatic shifts in social dynamics, advantaging those with the technology and increasing inequality in access. Neuralink technology can be expensive and complex, making it only available to a certain group of people. (Ian, 2024) Neuralink technology may widen the gap between the rich and poor, as only the wealthy can access its health and mental benefits. This unequal access could lead to disparities in educational and professional opportunities, enhancing the mental abilities of those who use it. Additionally, it may create social justice issues for those without access, leading to feelings of discrimination. While the technology has great potential to improve lives, it also poses significant social challenges that require policies to ensure equitable access and mitigate negative impacts on human interaction.

13. Conclusion and Recommendations

Neuralink technology represents a revolutionary step towards the future, carrying with it great potential to improve the quality of life and enhance human capabilities. However, there are legal and economic challenges that require careful treatment to ensure the safe and ethical use of this technology. It requires international cooperation to develop effective legal frameworks that support innovation and protect individuals' rights, as well as economic strategies that promote equitable access to these new technologies. Striking a balance between innovation and rights protection will enable communities to fully leverage the benefits of Neuralink, contributing to building a brighter and more advanced future. Below are recommendations for legal, economic and ethical challenges. A proposal for the Egyptian legislator to fill the legal gaps: Protecting neural data and not just personal data

Strict laws must be put in place to protect the neural data collected by Neuralink devices. These laws could include clear requirements to obtain users' consent before collecting or using their neural data.

All neural data must be strongly encrypted to ensure no unauthorized access. Advanced encryption techniques can be used to protect data during transmission and storage. Privacy:

Strict laws are required to protect privacy Bonaci, T., Calo, R., & Chizeck, H. (2014), and ensure neural data is used legally and with consent, following the EU's GDPR guidelines. The community must be made aware of the benefits and risks of Neuralink technology to ensure everyone understands the technology and how to use it safely and responsibly.

13.1. Legal Responsibility

A legal framework must be established that specifies liability in the event of problems or damages resulting from the use of Neuralink devices. This could include limitation of liability between the manufacturer, users, and operators.

Insurance: Insurance for nervous devices can be a solution to cover potential damages that may result from their use, providing additional protection for users. Regulation and licenses:

High security standards must be developed for Neuralink devices to ensure that they are not vulnerable to hacking. These standards can include periodic security testing and ongoing software updates. Users must be trained on how to protect their nervous systems from cyber-attacks, and be made aware of the potential risks and how to deal with them.

A proposal to improve economic aspects Neuralink technology holds huge economic potential, but it also comes with economic challenges. Here are some recommendations: Investment and development: Investments in research and development of Neuralink technology should be encouraged by providing tax incentives and financial support to startups in this field. Cooperation between the public and private sectors can be strengthened to accelerate the development of this technology and ensure that its benefits are distributed fairly. Impact on the labor market: Training programs must be provided to rehabilitate workers whose jobs may be affected by Neuralink technology, to ensure their transition to new jobs in the fields of neural- technology. Neuralink technology can contribute to creating new job opportunities in the areas of research and development, manufacturing, maintenance, and training.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6: 5025-5040, 2024
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Cost and access: Financial support must be provided to individuals who are unable to afford neurological devices to ensure that they reach the largest possible number of people. Policies must be put in place to ensure that the benefits of Neuralink technology are distributed fairly among all segments of society, regardless of economic status. Ethical and social aspects Neuralink technology raises many ethical and social questions. Here are some recommendations: Equality: Policies must be put in place to ensure that the benefits of Neuralink technology are distributed fairly among all segments of society, regardless of economic status. The community must be made aware of the benefits and risks of Neuralink technology to ensure everyone understands the technology and how to use it safely and responsibly. Impact on human identity: A broad societal discussion must be opened about the impact of Neuralink technology on human identity and how to deal with the ethical challenges associated with it. - Ethical research should be supported to study the impact of Neuralink technology on human identity and provide recommendations on how to deal with these challenges.

Copyright:

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Edelweiss Applied Science and Technology
ISSN: 2576-8484
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