A Study on Neurotechnology and Privacy Protecting Brain Data in Brain Machine Interfaces

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Abstract*—The rapid advancement of neurotechnology has significantly enhanced our ability to record, interpret, and manipulate brain activity, leading to transformative applications in healthcare, communication, and human-computer interaction. However, these developments have also raised critical privacy concerns regarding the collection, storage, and use of brain data. Unlike other forms of personal data, brain data provides an intimate window into thoughts, emotions, and cognitive processes, making it highly sensitive and vulnerable to misuse, unauthorized access, and potential manipulation. This study explores the intersection of neurotechnology and brain data privacy, examining the ethical, legal, and societal implications of brain-computer interfaces (BCIs), neuroimaging, and cognitive monitoring devices. The study used both primary and secondary data. Primary data has been collected from 200 respondents using convenient sampling with structured questionnaires. From figures it is found that 22.28% of the respondents between the age group 21–30 years have stated that potential for manipulation of control is the biggest concern regarding brain machine interfaces and 17.82% of the respondents pursuing under graduation have agreed that neurotechnology has the potential to revolutionise healthcare. In conclusion, the findings state that while neurotechnology offers promising advancements, it also poses unprecedented challenges that require immediate attention. A balanced approach—ensuring innovation while upholding mental privacy and ethical integrity—is essential. Policymakers, researchers, and industry leaders must collaborate to establish robust privacy frameworks, enhance public awareness, and promote responsible development of neurotechnology to safeguard individuals' cognitive autonomy in the digital age.*

Index Terms*—Neurotechnology, Privacy, Digital, Access, Brain Data.*

1. INTRODUCTION

Neurotechnology, an interdisciplinary field combining neuroscience, artificial intelligence, and engineering, has made significant strides in decoding and interpreting brain activity. Innovations such as brain-computer interfaces (BCIs), neuroimaging, and neural implants have unlocked new possibilities in healthcare, education, and human-computer interaction. These advancements offer immense benefits, from assisting individuals with neurological disorders to enhancing cognitive capabilities. This study aims to explore the intersection of neurotechnology and privacy, focusing on the legal, ethical, and technological challenges associated with brain data collection, storage, and usage.

The study of neurotechnology and brain data privacy has evolved significantly over the past few decades, driven by rapid advancements in neuroscience, artificial intelligence, and data science. Initially, research in neurotechnology focused primarily on medical applications, such as treating neurological disorders through brain-computer interfaces (BCIs) and neuroimaging techniques like functional MRI (fMRI) and electroencephalography (EEG). However, as technology advanced, the ability to decode and interpret brain signals expanded beyond clinical settings to consumer applications, cognitive enhancement, and even neuromarketing. This shift raised significant ethical and legal concerns regarding the privacy and security of brain data. The early 2000s saw growing discussions on the implications of neurotechnology for individual autonomy and mental privacy, particularly with the emergence of BCIs that could read and potentially manipulate neural activity. Scholars and policymakers began recognizing the unique sensitivity of brain data, leading to calls for stronger regulatory frameworks. With the rise of artificial intelligence and big data analytics, concerns about neuro-surveillance, cognitive hacking, and mental privacy breaches intensified, prompting legal scholars to explore whether existing data protection laws, such as the GDPR, adequately cover neurodata.

In India, the regulation of neurotechnology and brain data privacy is still in its nascent stages, but the government has taken some steps toward addressing emerging concerns. The Digital Personal Data Protection Act, 2023 (DPDP Act) provides a broad legal framework for data privacy, including sensitive personal data, which could potentially cover neurodata. However, specific regulations addressing brain data privacy and neurotechnology applications are yet to be developed. The Indian Council of Medical Research (ICMR) has issued ethical guidelines for biomedical and health research, which may have implications for neurotechnology-related studies. Additionally, institutions like the Department of Biotechnology (DBT) and the National Brain Research Centre (NBRC) are actively engaged in neurotechnology research, focusing on medical applications such as BCIs and neuroimaging. While India has not yet enacted dedicated legislation on neurorights or cognitive privacy, discussions on AI regulation, data security, and bioethics indicate a growing awareness of the need for legal safeguards in this area.

Several factors influence the intersection of neurotechnology and brain data privacy, including technological advancements, legal frameworks, ethical considerations, cybersecurity risks, and public awareness. The rapid development of BCIs, neuroimaging, and AI-driven neural decoding has expanded the scope of brain data collection, raising concerns about unauthorized access, data misuse, and cognitive surveillance. The absence of specific legal regulations on neurodata protection in many countries, including India, creates a regulatory gap, leaving individuals vulnerable to privacy violations. Ethical concerns regarding informed consent, cognitive liberty, and mental integrity further complicate the issue, as neurotechnology has the potential to manipulate thoughts and emotions. Additionally, cybersecurity threats, such as hacking of brain data and neuro-surveillance, pose significant risks to individuals' autonomy and privacy. Lastly, public awareness and societal perception play a crucial role—while neurotechnology offers numerous benefits, lack of awareness about its risks can lead to unregulated and unethical usage. Addressing these factors requires a multidisciplinary approach involving law, technology, ethics, and policy-making.

Current trends in neurotechnology involve BCIs, neuroimaging, and AI-driven brain signal analysis gaining prominence in healthcare, consumer technology, and even military applications. Companies like Neuralink, OpenBCI, and Emotiv are developing non-invasive and implantable BCIs for communication, cognitive enhancement, and medical treatments. In India, while direct neuroprivacy regulations are lacking, increasing debates on AI ethics, digital privacy laws, and biomedical research guidelines indicate a growing awareness. The push for secure neural data encryption, ethical AI integration, and stricter data protection laws is expected to shape the future of neurotechnology regulation.

India is still in the early stages of regulating neurotechnology and brain data privacy, whereas some countries have taken significant steps in this area. Chile is a global pioneer, having introduced "neurorights" into its constitution, ensuring protections against unauthorized brain data collection and cognitive manipulation. The European Union (EU), through the General Data Protection Regulation (GDPR), offers a strong privacy framework that could potentially cover neurodata, though specific laws on brain data are still evolving. The United States has ongoing discussions on neuroprivacy, particularly through agencies like DARPA and the NIH, but lacks dedicated federal legislation on brain data protection. Meanwhile, China has been investing heavily in neurotechnology, particularly in AI-driven brain research, but concerns remain about potential state surveillance applications. With increasing advancements in BCIs and AI-driven neural analysis, India may soon need to adopt specific neuroprivacy regulations in line with global trends.

2. OBJECTIVES

- To study the biggest concern regarding brain machine interfaces.
- To explore neurotechnology's potential to revolutionise healthcare.
- To know the use of brain machine interfaces in raising significant ethical concerns.
- To study the trust in public companies to safeguard data.

3. LITERATURE REVIEW

Sheri Alpert (2007) explored legal protections against forced neuroimaging, drawing parallels with Fourth Amendment rights against unreasonable searches. The author argues that neural scans could expose highly sensitive personal information, making compulsory brain data collection legally and ethically problematic.

Michele Farisco & Kathinka Evers (2016) discussed infant consciousness and the ethical challenges of early cerebral communication technologies. The authors examine neuroscientific progress in studying infant cognition and the ethical concerns surrounding brain-monitoring in children.

Anna Wexler & Karen Rommelfanger (2016) explored privacy challenges posed by wearable neurotechnology, particularly devices that record brain signals. The authors highlight concerns related to user autonomy, data collection practices, and inadequate regulatory frameworks, emphasizing the need for better governance to prevent misuse of brain data.

Marcello Ienca & Roberto Andorno (2017) examined the ethical and legal implications of advanced neurotechnologies, questioning whether existing privacy laws are sufficient to protect mental data. The authors propose the concept of "neurorights", advocating for new legal frameworks that specifically address mental and brain privacy in response to the rise of BCIs.

Timothy J. Brown (2021) discussed the potential privacy risks associated with the open sharing of neuroscience data and emphasizes the importance of legal safeguards. The authors argue that while open data-sharing accelerates scientific progress, it also increases the risk of misuse, necessitating legal prohibitions against harmful applications to protect individuals' mental privacy.

Simon Hanisch, Patricia Arias-Cabarcos & Javier Parra-Arnau (2021) examined privacy-protecting techniques for behavioral biometric data, including brain activity, voice, eye-gaze, and heart rate. The authors analyze different anonymization methods used to safeguard neurodata and discuss their limitations, highlighting the growing risks of AI-based neural data tracking.

Maryna Kapitonova & Philipp Kellmeyer (2022) presented a systematic framework for ensuring privacy and cybersecurity in BCI applications. The paper emphasizes the importance of privacy-by-design principles, suggesting that neurotechnology developers must integrate strong encryption, secure data storage, and user-consent mechanisms to protect sensitive neural information.

Clara Baselga-Garriga & Paloma Rodriguez (2022) explored the potential and risks of BCIs, particularly in decoding speech for medical applications. While BCIs offer groundbreaking possibilities for patients with disabilities, the authors highlight concerns about privacy, autonomy, and ethical governance.

Abel Wajnerman & Pablo Lopez-Silva (2022) focused on the growing ability of neurotechnology to decode conscious mental states with high accuracy. The authors argue that these advances raise critical ethical questions about individual control over brain data and the risks of neural surveillance.

Dov Greenbaum & Mark Gerstein (2023) critiqued the "neuro-hype" surrounding brain research, arguing that unrealistic expectations about neurotechnology could lead to public misinformation. The study emphasizes the need for accurate communication about the potential and limitations of brain data analysis.

Sjors Ligthart et al. (2023) mapped the ethical and legal foundations of neurorights, focusing on key principles such as mental privacy, cognitive liberty, and mental integrity. The work provides policy recommendations for integrating these concepts into legal and human rights frameworks to prevent unauthorized access and manipulation of brain data.

Emiram Kablo & Patricia Arias (2023) analyzed the expansion of BCIs beyond medical applications into entertainment, wellness, and marketing. The authors raise concerns about the commodification of brainwave data and the potential for AI-driven privacy attacks, such as brain-to-speech and brain-to-image decoding.

Nuffield Council on Bioethics (2024) outlined developments in neuroimaging, neuromodulation, and BCIs, addressing their ethical implications. It discusses the current state of neurotechnology in clinical practice and identifies key privacy and consent challenges that must be addressed as these technologies advance.

Neurorights Foundation (2024) assessed the privacy practices of consumer neurotechnology devices, emphasizing risks associated with data collection, storage, and user consent. Neurotechnology is now expanding into the consumer market, raising concerns about brain data commercialization and potential misuse.

Francis X. Shen & Dena M. Grommet (2024) explored U.S. public perceptions of brain data sensitivity, revealing that some individuals consider neural data less sensitive than other private information, such as social security numbers. The findings raise concerns about public awareness of neuroprivacy risks and the need for stronger legal protections.

American University Washington College of Law (2024) examined the privacy and data protection implications of neurotechnology. The study evaluates legal frameworks under Convention 108+ and provides recommendations on strengthening data protection laws to cover emerging neurotech risks.

Marcello Ienca (2024) argued that brain privacy rights alone are insufficient and that neurotechnology requires expanded protections for freedom of thought. The author highlights the growing commercialization of brain data and the threat of AI-driven cognitive manipulation, advocating for stronger legal interventions.

Ruiz-Vanoye, Jorge A. & Diaz-Parra (2024) discussed the rapid development of neurotechnology and its implications for neurosecurity. By drawing parallels with established cybersecurity practices, the authors emphasize the need for robust encryption and secure communication protocols to protect brain data from cyber threats.

Pablo Lopez-Silva (2024) defined mental privacy as the right to control access to one's own neural data and the information derived from it. The study contributes to the ongoing debate on cognitive privacy, analyzing different positions on brain data ownership and ethical safeguards.

Anita Jwa (2024) examined how AI and Big Data analytics are enabling brain data interpretation, prediction, and manipulation. The study highlights the risks of brain data re-identification and commercialization, emphasizing the need for stronger legal protections to prevent misuse.

Adrian Thorogood (2024) explored population neuroscience, integrating genomics, epidemiology, and neuroscience to understand brain health over a lifetime. The study discusses the importance of data-sharing strategies while ensuring effective data management and privacy protection.

4. METHODOLOGY

The research method employed is empirical research, which involves the collection and analysis of data to explore the real-world phenomena being investigated. A total of 202 samples were collected to understand various factors related to the study. The samples were chosen using a convenient sampling method, which allows for selecting participants who are readily available in specific locations, in this case, public areas in and around Chennai, Tamil Nadu. The study considers both independent and dependent variables. The independent variables—gender, age, educational qualification, occupation, and marital status—are the factors that may influence the respondents' perceptions or knowledge about neurotechnology and brain data privacy. The dependent variables are the biggest concern regarding brain machine interfaces, neurotechnology's potential to revolutionise healthcare, and trust in private companies in protecting brain data. The software used to analyse the data is SPSS (Statistical Package for the Social Sciences), a widely used platform for data analysis in research.

5. DATA ANALYSIS

Figure 1

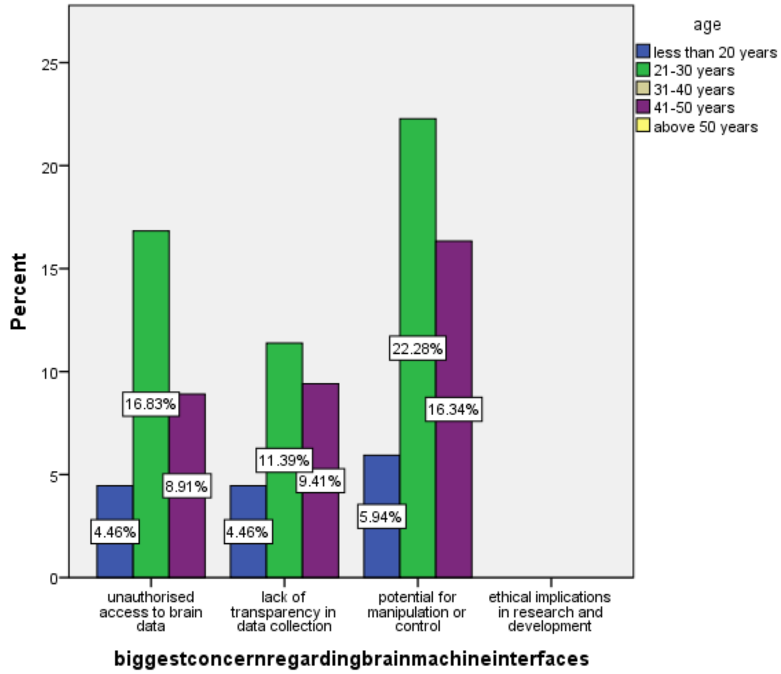

Figure 1: Relation between age of the respondents and the biggest concern regarding brain machine interfaces.

Figure 2

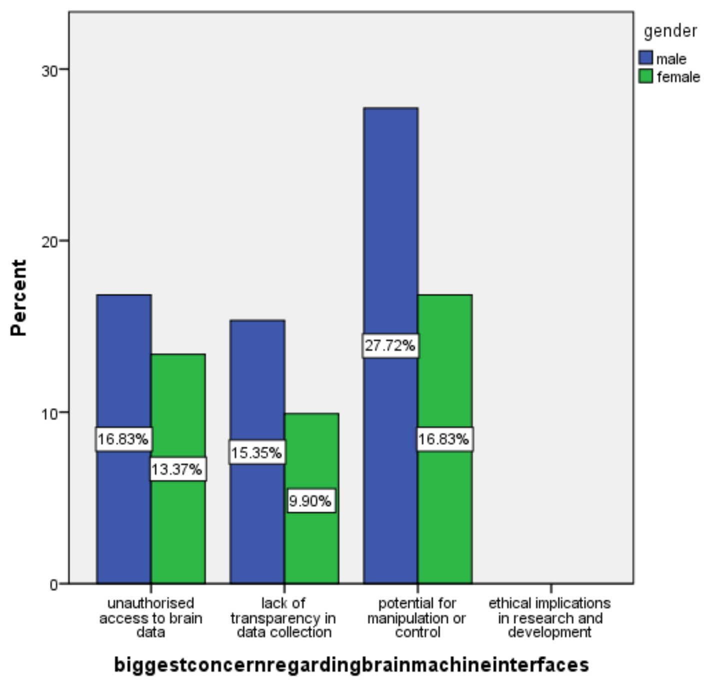

Figure 2: Relation between gender of the respondents and the biggest concern regarding brain machine interfaces.

Figure 3

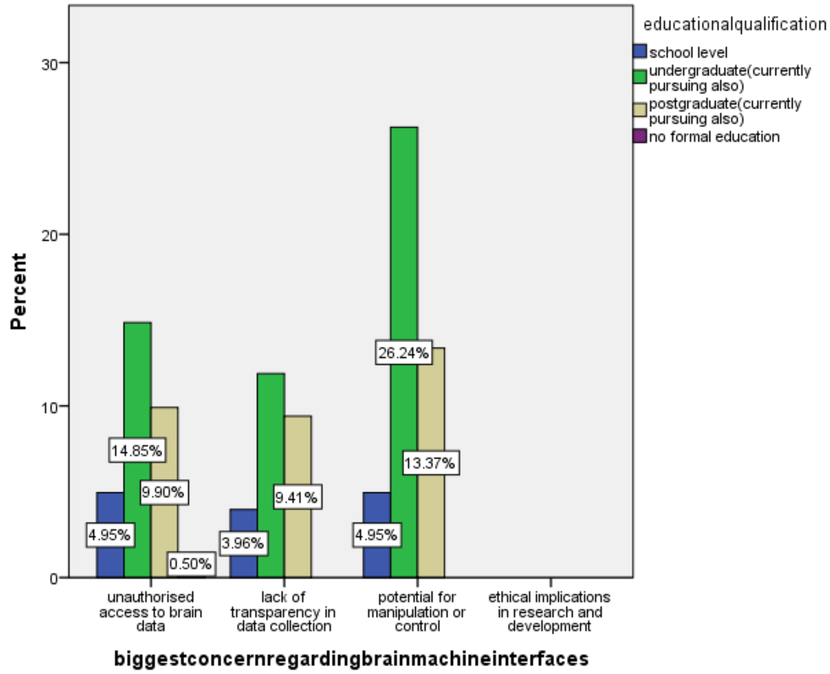

Figure 3: Relation between education qualification of the respondents and the biggest concern regarding brain machine interfaces.

Figure 4

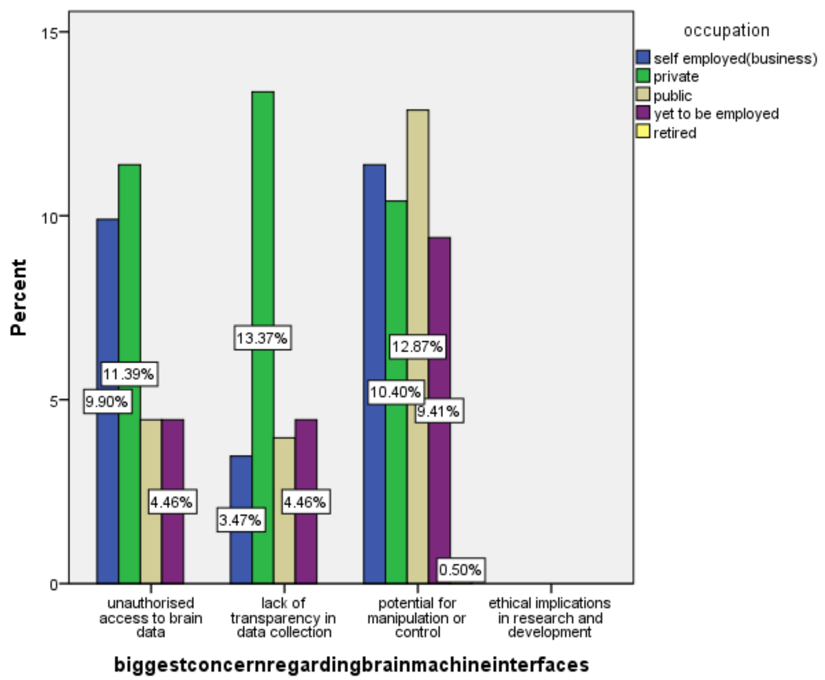

Figure 4: Relation between occupation of the respondents and the biggest concern regarding brain machine interfaces.

Figure 5

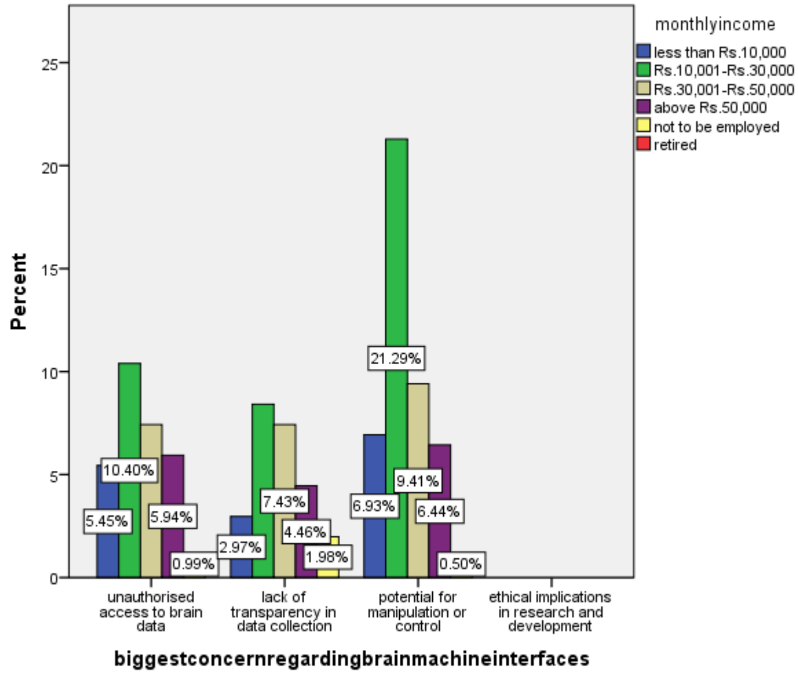

Figure 5: Relation between monthly income of the respondents and the biggest concern regarding brain machine interfaces.

Figure 6

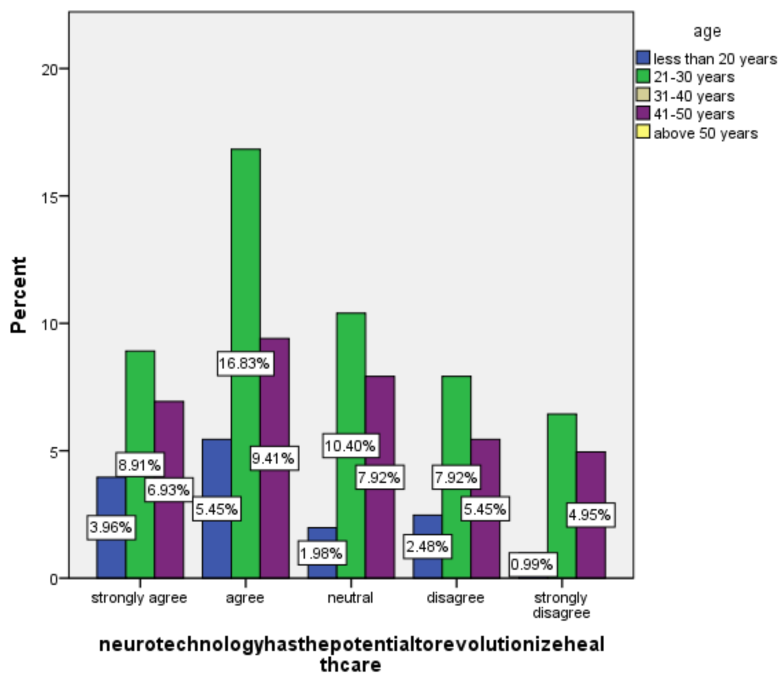

Figure 6: Relation between age of the respondents and their agreeability towards neurotechnology having the potential to revolutionise healthcare.

Figure 7

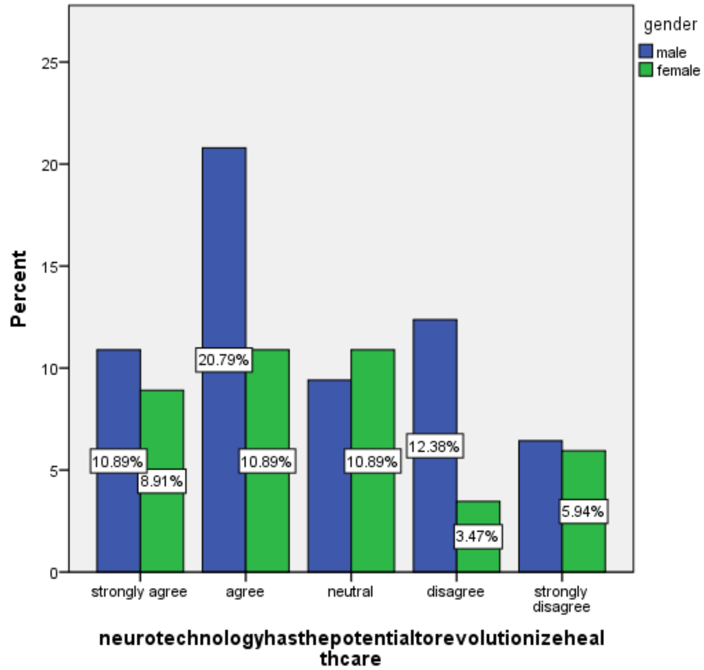

Figure 7: Relation between gender of the respondents and their agreeability towards neurotechnology having the potential to revolutionise healthcare.

Figure 8

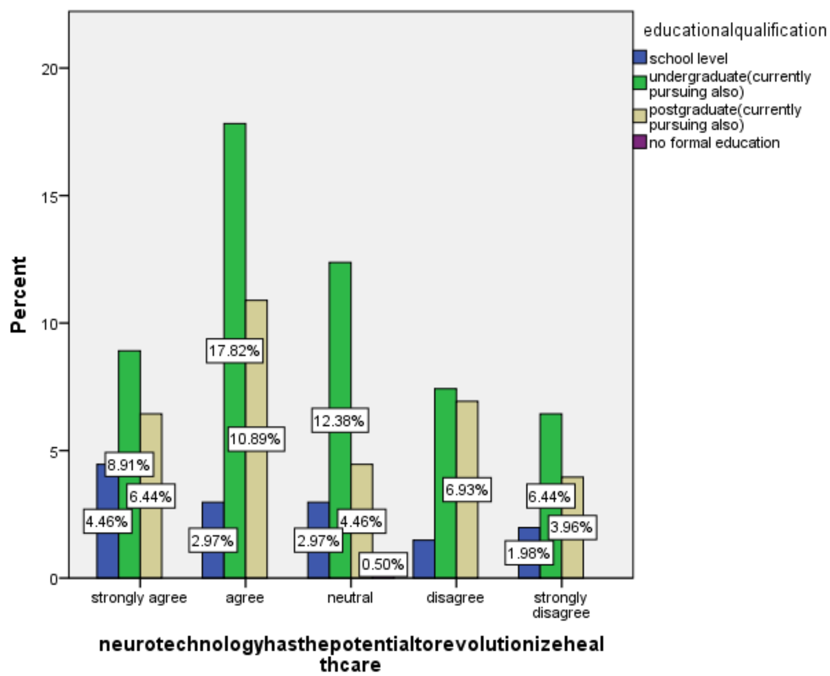

Figure 8: Relation between educational qualification of the respondents and their agreeability towards neurotechnology having the potential to revolutionise healthcare.

Figure 9

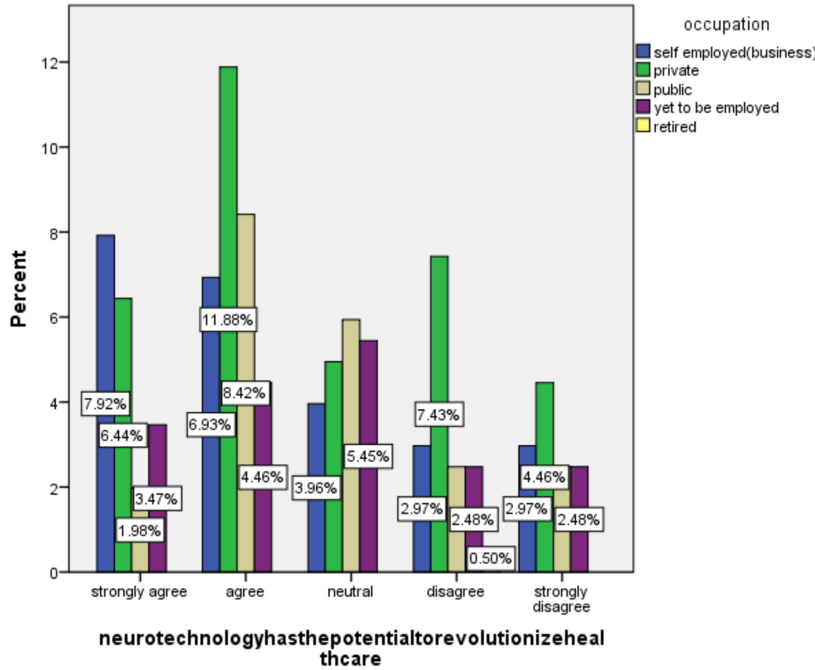

Figure 9: Relation between occupation of the respondents and their agreeability towards neurotechnology having the potential to revolutionise healthcare.

Figure 10

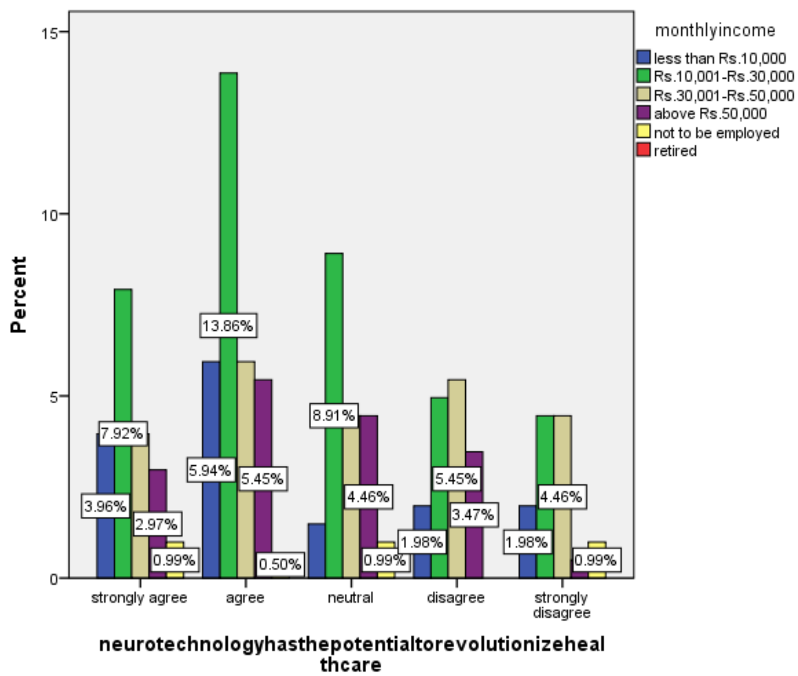

Figure 10: Relation between monthly income of the respondents and their agreeability towards neurotechnology having the potential to revolutionise healthcare.

Figure 11

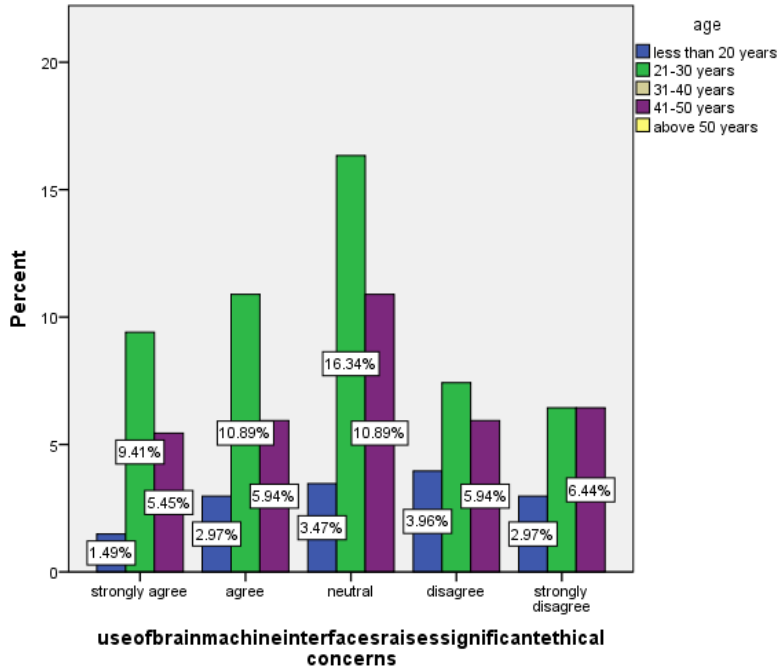

Figure 11: Relation between age of the respondents and their agreeability towards use of brain machine interface raising significant ethical concerns.

Figure 12

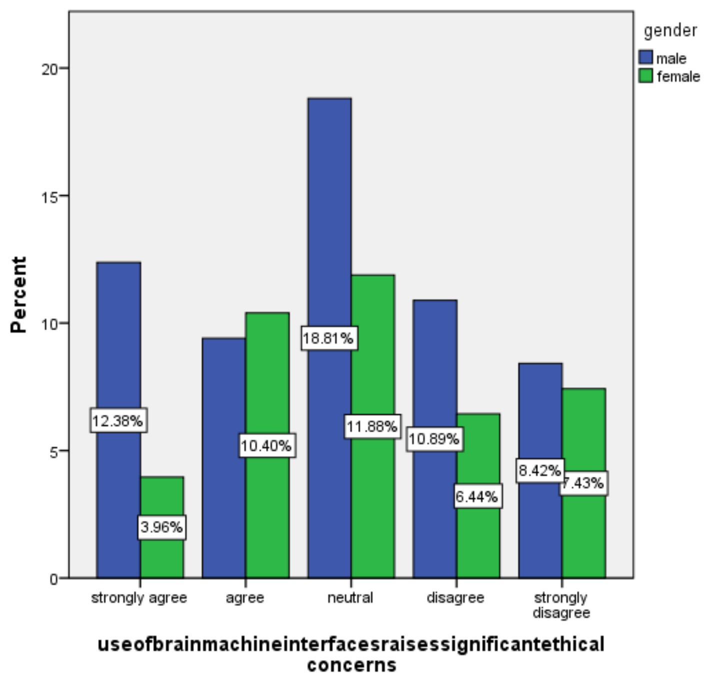

Figure 12: Relation between gender of the respondents and their agreeability towards use of brain machine interface raising significant ethical concerns.

Figure 13

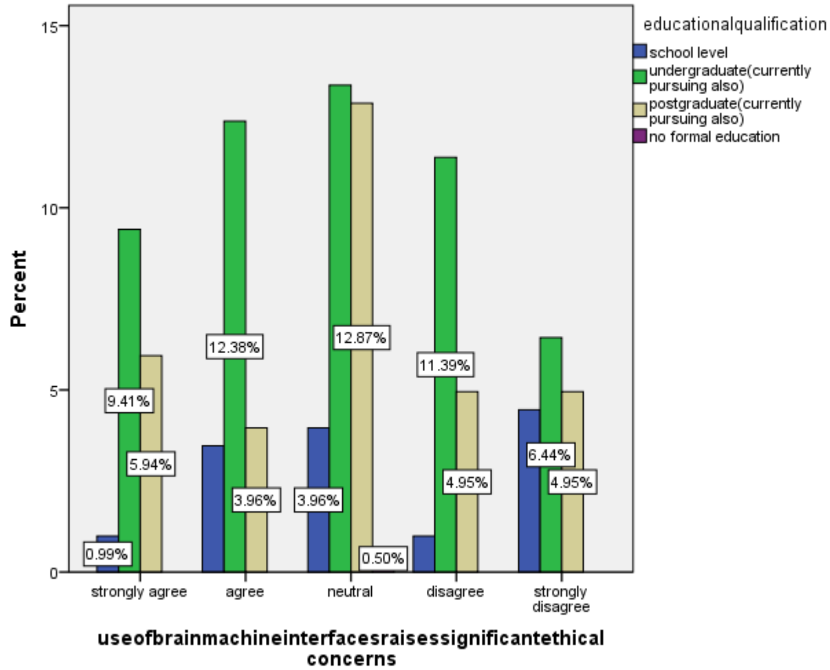

Figure 13: Relation between educational qualification of the respondents and their agreeability towards use of brain machine interface raising significant ethical concerns.

Figure 14

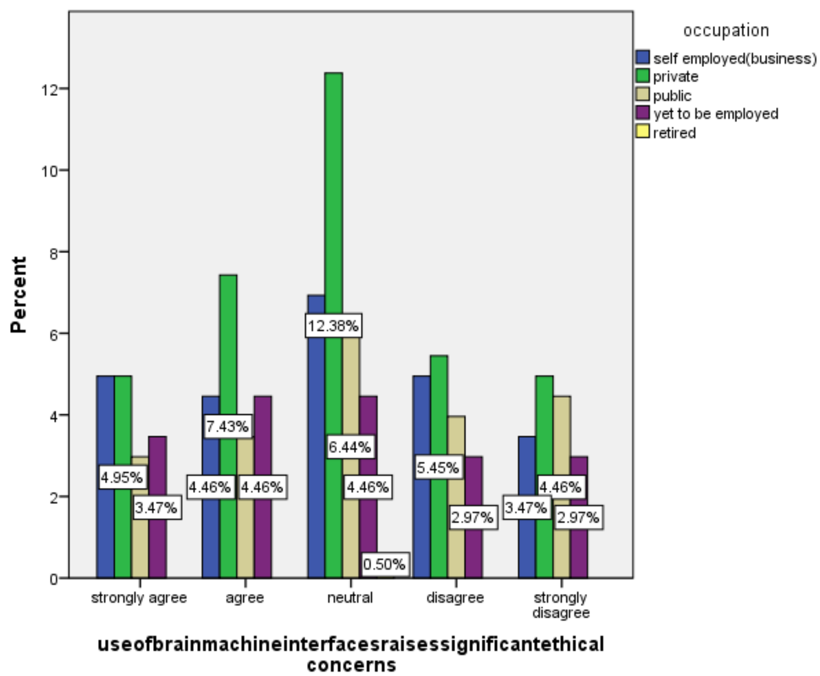

Figure 14: Relation between occupation of the respondents and their agreeability towards use of brain machine interface raising significant ethical concerns.

Figure 15

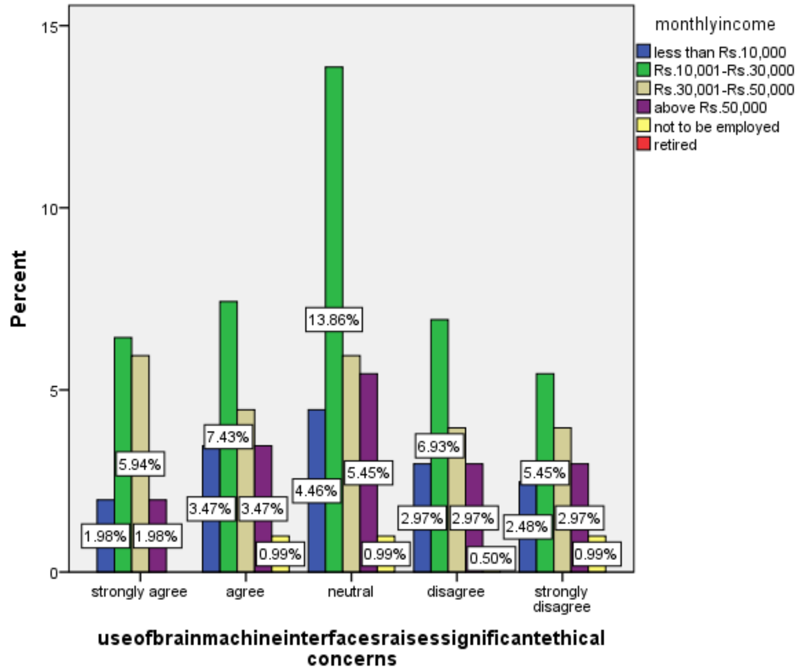

Figure 15: Relation between monthly income of the respondents and their agreeability towards use of brain machine interface raising significant ethical concerns.

Figure 16

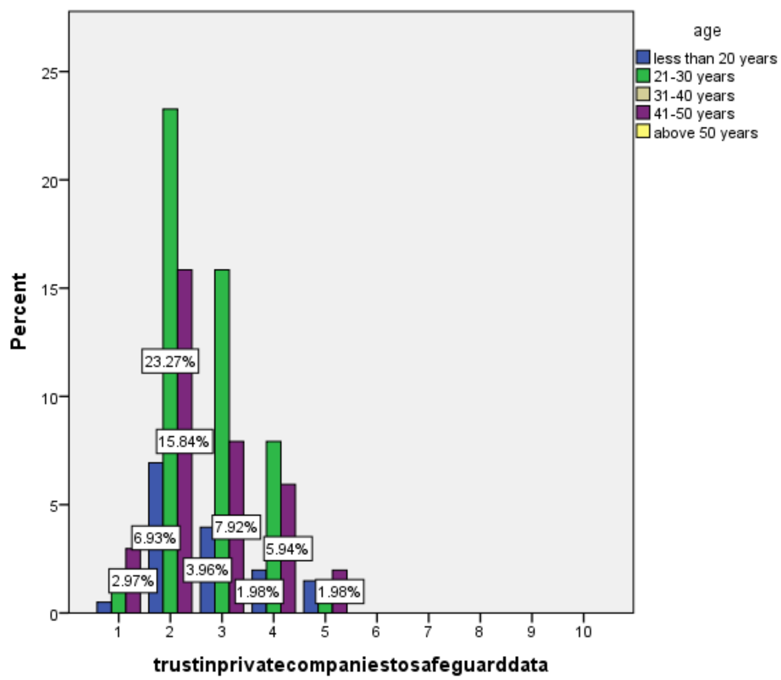

Figure 16: Relation between age of the respondents and their rating towards trust in private companies to safeguard data.

Figure 17

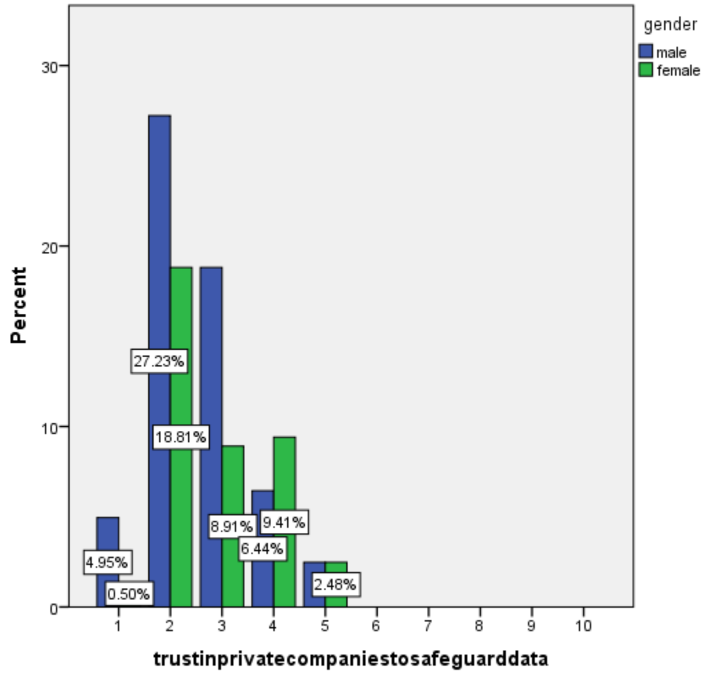

Figure 17: Relation between gender of the respondents and their rating towards trust in private companies to safeguard data.

Figure 18

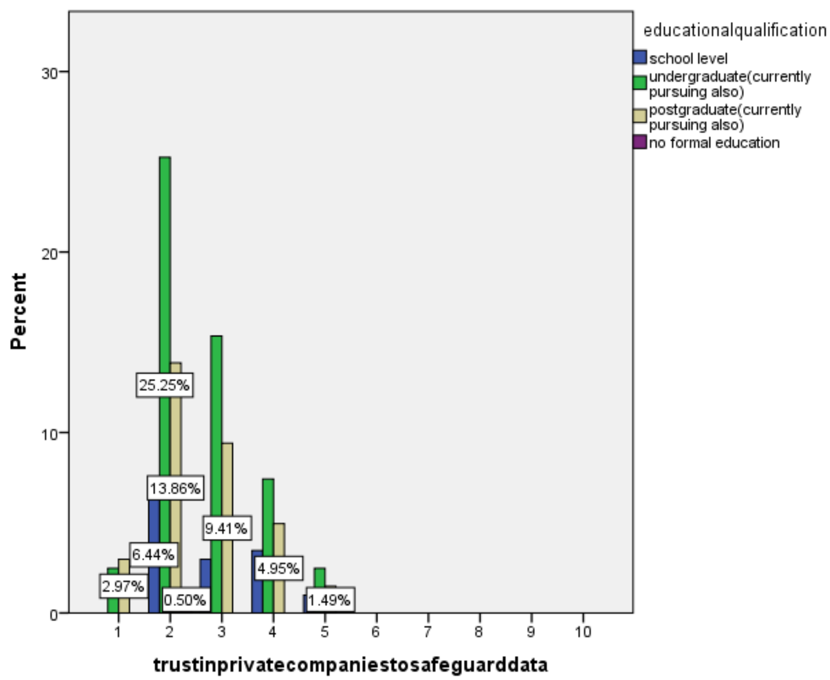

Figure 18: Relation between educational qualification of the respondents and their rating towards trust in private companies to safeguard data.

Figure 19

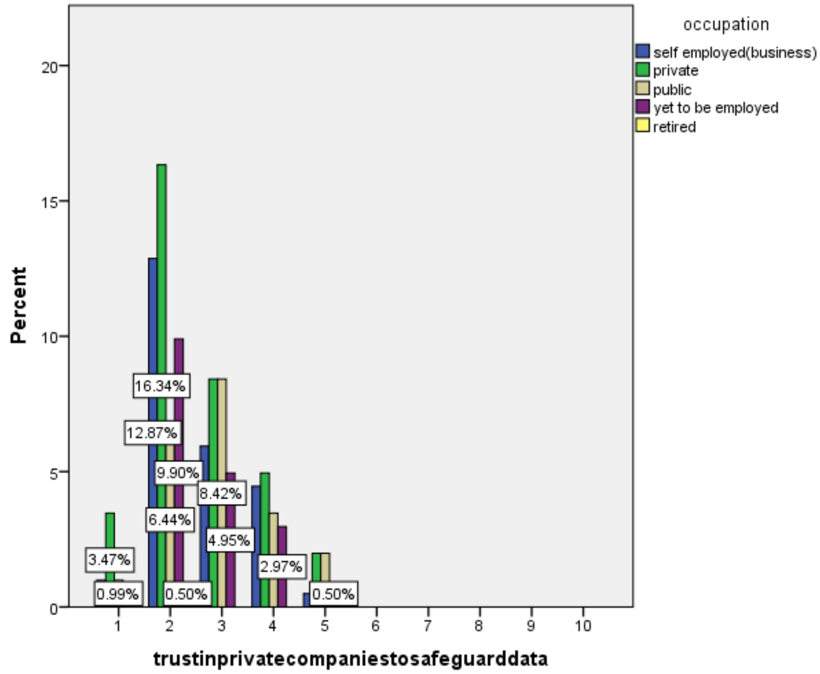

Figure 19: Relation between occupation of the respondents and their rating towards trust in private companies to safeguard data.

Figure 20

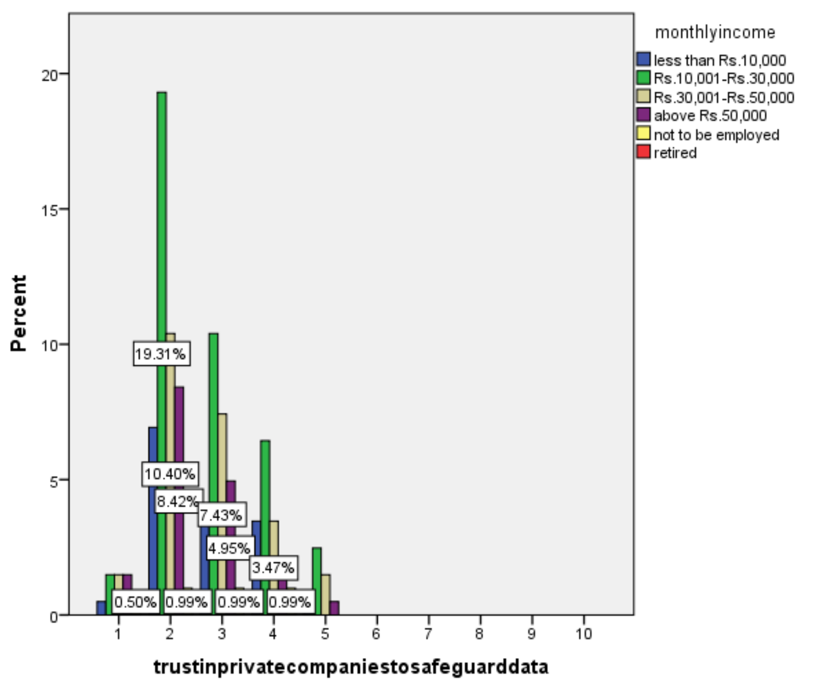

Figure 20: Relation between monthly income of the respondents and their rating towards trust in private companies to safeguard data.

Figure 21: Chi-Square Test — Age and Biggest Concern Regarding Brain Machine Interfaces

H_0: There is no significant association between age and biggest concern regarding Brain Machine Interfaces.

H_1: There is a significant association between age and biggest concern regarding Brain Machine Interfaces.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
age * biggestconcernregarding brainmachineinterfaces	202	100.0%	0	0.0%	202	100.0%

age * biggestconcernregardingbrainmachineinterfaces Crosstabulation

Count

		biggestconcernregardingbrainmachineinterfaces			
		unauthorised access to brain data	lack of transparency in data collection	potential for manipulation or control	Total
age	less than 20 years	9	9	12	30
	21-30 years	34	23	45	102
	41-50 years	18	19	33	70
Total		61	51	90	202

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.710[a]	4	.789
Likelihood Ratio	1.720	4	.787
Linear-by-Linear Association	.688	1	.407
N of Valid Cases	202		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.57.

Figure 21: Chi-square test between age and biggest concern regarding Brain Machine Interfaces.

Figure 22: Chi-Square Test — Gender and Use of Brain Machine Interfaces Raising Ethical Concerns

H_0: There is no significant association between gender and use of brain machine interfaces raising significant ethical concerns.

H_1: There is a significant association between gender and use of brain machine interfaces raising significant ethical concerns.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
gender * useofbrainmachineinterfacesraisessignificantethicalconcerns	202	100.0%	0	0.0%	202	100.0%

gender * useofbrainmachineinterfacesraisessignificantethicalconcerns Crosstabulation

Count

		useofbrainmachineinterfacesraisessignificantethicalconcerns					Total
		strongly agree	agree	neutral	disagree	strongly disagree	
gender	male	25	19	38	22	17	121
	female	8	21	24	13	15	81
Total		33	40	62	35	32	202

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.804[a]	4	.147
Likelihood Ratio	6.974	4	.137
Linear-by-Linear Association	.960	1	.327
N of Valid Cases	202		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 12.83.

Figure 22: Chi-square test between gender and use of brain machine interfaces raising significant ethical concerns.

Figure 23: Chi-Square Test — Age and Trust in Private Companies to Safeguard Data

H_0: There is no significant association between age and trust in private companies to safeguard data.

H_1: There is a significant association between age and trust in private companies to safeguard data.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
age * trustinprivatecompaniestosafeguarddata	202	100.0%	0	0.0%	202	100.0%

age * trustinprivatecompaniestosafeguarddata Crosstabulation

Count

		trustinprivatecompaniestosafeguarddata					Total
		1	2	3	4	5	
age	less than 20 years	1	14	8	4	3	30
	21-30 years	4	47	32	16	3	102
	41-50 years	6	32	16	12	4	70
Total		11	93	56	32	10	202

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.696[a]	8	.681
Likelihood Ratio	5.401	8	.714
Linear-by-Linear Association	.251	1	.616
N of Valid Cases	202		

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is 1.49.

Figure 23: Chi-square test between age and trust in private companies to safeguard data.

6. RESULT

From Figure 1, it is derived that 22.28% of the respondents between the age group 21–30 years have stated that potential for manipulation of control is the biggest concern regarding brain machine interfaces. From Figure 2, it is derived that 27.72% of the respondents have stated that potential for manipulation or control is the biggest concern regarding brain machine interfaces. From Figure 3, it is derived that 26.24% of the respondents have stated that potential for manipulation or control is the biggest concern regarding brain machine interfaces. From Figure 4, it is derived that 13.37% of the respondents in the private sector have stated that lack of transparency in data collection is the biggest concern regarding brain machine interfaces. From Figure 5, it is derived that 21.29% of the respondents receiving ₹10,001–₹30,000 have stated that potential for manipulation or control is the biggest concern regarding brain machine interfaces.

From Figure 6, it is derived that 16.83% of the respondents between the age group 21–30 years have agreed that neurotechnology has the potential to revolutionise healthcare. From Figure 7, it is derived that 20.79% of the male respondents and 10.89% of the female respondents have agreed that neurotechnology has the potential to revolutionise healthcare. From Figure 8, it is derived that 17.82% of the respondents pursuing undergraduate studies have agreed that neurotechnology has the potential to revolutionise healthcare. From Figure 9, it is derived that 11.88% of the respondents in the private sector have agreed that neurotechnology has the potential to revolutionise healthcare. From Figure 10, it is derived that 13.86% of the respondents receiving ₹10,001–₹30,000 have agreed that neurotechnology has the potential to revolutionise healthcare.

From Figure 11, it is derived that 16.34% of the respondents between the age group 21–30 years have stated neutral for the use of brain machine interface raising significant ethical concerns. From Figure 12, it is derived that 18.81% of the male respondents and 11.88% of the female respondents have stated neutral for the use of brain machine interface raising significant ethical concerns. From Figure 13, it is derived that 12.38% of the respondents pursuing undergraduate studies have agreed that the use of brain machine interface raises significant ethical concerns. From Figure 14, it is derived that 12.38% of the self-employed respondents have stated neutral for the use of brain machine interface raising significant ethical concerns. From Figure 15, it is stated that 13.86% of the respondents receiving ₹10,001–₹30,000 have stated neutral for the use of brain machine interface raising significant ethical concerns.

From Figure 16, it is derived that 23.27% of the respondents between the age group 21–30 years have rated 2 out of 10 on the trust in private companies to safeguard data. From Figure 17, it is derived that 27.23% of the male respondents have rated 2 out of 10 on the trust in private companies to safeguard data. From Figure 18, it is derived that 25.25% of the respondents pursuing undergraduate studies have rated 2 out of 10 on the trust in private companies to safeguard data. From Figure 19, it is derived that 16.34% of the self-employed respondents have rated 2 out of 10 on the trust in private companies to safeguard data. From Figure 20, it is derived that 19.23% of the respondents receiving ₹10,001–₹30,000 have rated 2 out of 10 on the trust in private companies to safeguard data.

From Figure 21, the p value is 1.710, which is greater than 0.005, and the null hypothesis is accepted — there is no significant association between age and biggest concern regarding Brain Machine Interfaces. From Figure 22, the p value is 6.804, which is greater than 0.005, and the null hypothesis is accepted — there is no significant association between gender and use of brain machine interfaces raising significant ethical concerns. From Figure 23, the p value is 5.696, which is greater than 0.005, and the null hypothesis is accepted — there is no significant association between age and trust in private companies to safeguard data.

7. DISCUSSION

From the results inferred from Figure 1, 22.28% of respondents aged 21–30 years consider potential for manipulation or control as the biggest concern regarding brain-machine interfaces (BMIs). This suggests that younger individuals are particularly wary of external control over neural data, possibly due to their greater exposure to digital privacy concerns. From the results of Figures 2 and 3, with 27.72% and 26.24% of respondents respectively sharing the same concern, consistency across these figures suggests that a significant portion of the population perceives BMIs as a tool that could be misused for control or manipulation.

From Figure 4, 13.37% of private sector employees view lack of transparency in data collection as a primary concern, indicating that professionals in corporate environments may be more aware of data privacy risks and potential misuse by organizations. From Figure 5, 21.29% of respondents earning ₹10,001–₹30,000 are concerned about manipulation or control in BMIs, suggesting that individuals in this income range are more cautious about the ethical implications of neurotechnology due to concerns about accessibility, consent, and corporate control over brain data.

From Figure 6, 16.83% of respondents aged 21–30 years believe that neurotechnology has the potential to revolutionize healthcare, indicating a growing awareness among young adults about the benefits of neurotechnology in medical treatments and brain disorders. From Figure 7, the difference between 20.79% of male respondents and 10.89% of female respondents agreeing on neurotechnology’s healthcare potential suggests that men may be more optimistic or informed about neurotech advancements, while women may have more reservations. From Figure 8, 17.82% of undergraduate students recognize the revolutionary impact of neurotechnology in healthcare, indicating that students, being exposed to emerging research, are more receptive to its medical applications.

From Figures 9 and 10, lower agreement levels among private sector employees (11.88%) and those earning ₹10,001–₹30,000 (13.86%) indicate that working professionals may have more skepticism or less exposure to neurotechnology’s healthcare applications. From Figure 11, 16.34% of respondents aged 21–

30 years hold a neutral stance on the ethical concerns of BMIs, possibly indicating uncertainty or a lack of strong opinions due to limited awareness. From Figure 12, 18.81% of males and 11.88% of females being neutral on BMI-related ethical concerns suggests that men may be more open to debate while women may have clearer opinions on the matter.

From Figure 13, 12.38% of undergraduate students agree that BMIs raise ethical concerns, possibly reflecting their exposure to academic discussions on AI ethics, neuroscience, and privacy issues. From Figure 14, 12.38% of self-employed respondents are neutral on this issue, possibly indicating that entrepreneurs and freelancers may not yet see the direct impact of BMIs in their professional lives. From Figure 15, 13.86% of respondents earning ₹10,001–₹30,000 remain neutral on BMI ethics, suggesting that financial concerns may influence their perception of neurotechnological advancements.

From Figure 16, 23.27% of respondents aged 21–30 years rate their trust in private companies at 2 out of 10, indicating low confidence in corporate responsibility for brain data protection. From Figures 17 and 18, 27.23% of male respondents and 25.25% of undergraduate students expressed low trust in private companies, suggesting that men and students, who are likely more engaged in discussions around digital privacy and ethics, view corporate involvement in neurotechnology with skepticism. From Figures 19 and 20, 16.34% of self-employed respondents and 19.23% of respondents earning ₹10,001–₹30,000 also show low trust in private companies, reflecting concerns about data misuse, especially among middle-income earners who may have less access to legal recourse if their brain data is compromised.

From Figures 21, 22, and 23, all three chi-square tests show p values greater than 0.005, leading to acceptance of the null hypotheses. There is no significant association between age and biggest concern regarding Brain Machine Interfaces, between gender and use of brain machine interfaces raising significant ethical concerns, or between age and trust in private companies to safeguard data.

8. LIMITATIONS

This study on neurotechnology and brain data privacy has certain limitations. First, the analysis is largely theoretical and dependent on existing literature, which may not fully capture rapidly evolving advancements in neurotechnology and data protection laws. Additionally, public perception data is limited to specific demographic groups, making it difficult to generalize findings across diverse populations. The study also faces challenges in measuring real-world policy effectiveness, as regulatory frameworks are still developing, particularly in India. Lastly, while ethical concerns are discussed, technical aspects of neurodata security and encryption methods require further exploration to provide a comprehensive risk assessment. Future research should focus on empirical studies, cross-national policy comparisons, and technological solutions to enhance brain data privacy.

9. CONCLUSION

Neurotechnology has emerged as a groundbreaking field with immense potential to revolutionize healthcare, communication, and human-machine interaction. However, as brain-computer interfaces (BCIs), neuroimaging, and cognitive monitoring devices become more prevalent, concerns regarding privacy, security, and ethical implications have intensified. This study highlights the sensitivity of brain data, which, unlike conventional biometric data, provides access to a person's thoughts, emotions, and cognitive processes, making it highly susceptible to unauthorized access, misuse, and manipulation.

The discussion reveals that the potential for manipulation and control is one of the most significant public concerns regarding neurotechnology, particularly among younger demographics and economically diverse groups. There is also a lack of trust in private companies to safeguard brain data, with respondents expressing skepticism about transparency in data collection and protection mechanisms. While some acknowledge the potential of neurotechnology to advance healthcare, many remain neutral or cautious due to the ethical and legal uncertainties surrounding its use.

A comparison of global neuroprivacy regulations shows that while international initiatives, such as neurorights, aim to protect cognitive liberty, India's regulatory landscape is still evolving. Government initiatives in India have focused on scientific research and medical applications, but comprehensive legal protections for brain data remain inadequate. This highlights the urgent need for stronger policies, ethical guidelines, and data security measures to prevent the commercial exploitation and potential surveillance of neural information.

In conclusion, while neurotechnology offers promising advancements, it also poses unprecedented challenges that require immediate attention. A balanced approach—ensuring innovation while upholding mental privacy and ethical integrity—is essential. Policymakers, researchers, and industry leaders must collaborate to establish robust privacy frameworks, enhance public awareness, and promote responsible development of neurotechnology to safeguard individuals' cognitive autonomy in the digital age.

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