STM JOURNALS

Research & Reviews: A Journal of
Neuroscience

https://journals.stmjournals.com/rrjons/

ISSN: 2277-6427 (Online)
ISSN: 2348-7925 (Print)
Volume 16, Issue 1, 2026
January–April
DOI (Journal): 10.37591/RRJoNS

Review RRJoNS

Neural Implants & Brain–Computer Interfaces: Enhancing Human Intelligence or Violating Free Will?

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Abstract

The integration of neural implants with artificial intelligence creates opportunities to develop new implants and enhance current nanotechnologies. Although these advances hold significant potential for restoring neurological functions, they also introduce important ethical concerns. The rapid advancements in neural implants and brain–computer interfaces [BCIs] are revolutionizing human cognition, enabling enhanced intelligence, communication, and even thought-driven control of external devices. Although these technologies offer great promise in enhancing human abilities, they also bring serious ethical issues, especially related to autonomy and free will. This paper explores the duality of neural augmentation – whether it represents the pinnacle of human advancement or an intrusion upon fundamental freedoms. By analyzing current scientific developments, case studies, and ethical frameworks, we investigate whether BCIs empower individuals by expanding cognitive potential or pose risks of external manipulation and loss of self-determination. As society navigates the convergence of neuroscience and artificial intelligence, this discourse aims to assess the balance between innovation and ethical integrity in shaping the future of human intelligence.

Keywords: Artificial intelligence, brain–computer interface, ethics, neural implants, neuroprosthetics

INTRODUCTION

Brain–Computer Interfaces (BCI) and Neural Implants

A brain–computer interface (BCI) is technology created by research scientists and experts because of limitations faced by handicapped or mentally unstable individuals and to fully utilize the human brain. It is a technology that can transform brain signals into human actions independent of the peripheral nerves or muscles [1, 2]. It establishes direct communication between the human brain and external devices which is made possible by the innovative Brain–Computer Interface [BCI] technology, which eliminates the need for traditional neuromuscular channels. By monitoring and processing neural activity, typically using electroencephalography [EEG] or implanted electrodes, brain–computer interfaces [BCIs] enable users to communicate with computers, prosthetic arms and legs, and even speech synthesizers using only their thoughts [3, 4]. Cognitive augmentation, computer gaming, neuroprosthetics, and medical rehabilitation are just a few of the industries that BCI has transformed. BCIs assist those who are paralyzed or neurologically impaired by enabling communication and regaining lost motor skills. BCIs are redefining gaming by enabling players to engage with virtual worlds through brain activity. BCI does, however, have limitations, such as signal accuracy, privacy, and autonomy issues, and vulnerability, despite its immense potential (Figure 1) [5–7].

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Received Date: November 11, 2025
Accepted Date: February 11, 2026
Published Date: March 19, 2026

Citation: Shreeya Sampada Nayak, Vansh, Tushar, Yogesh Pilwan, Jyoti Kumari. Neural Implants & Brain–Computer Interfaces: Enhancing Human Intelligence or Violating Free Will? Research & Reviews: A Journal of Neuroscience. 2026; 16(1): 13–18p.

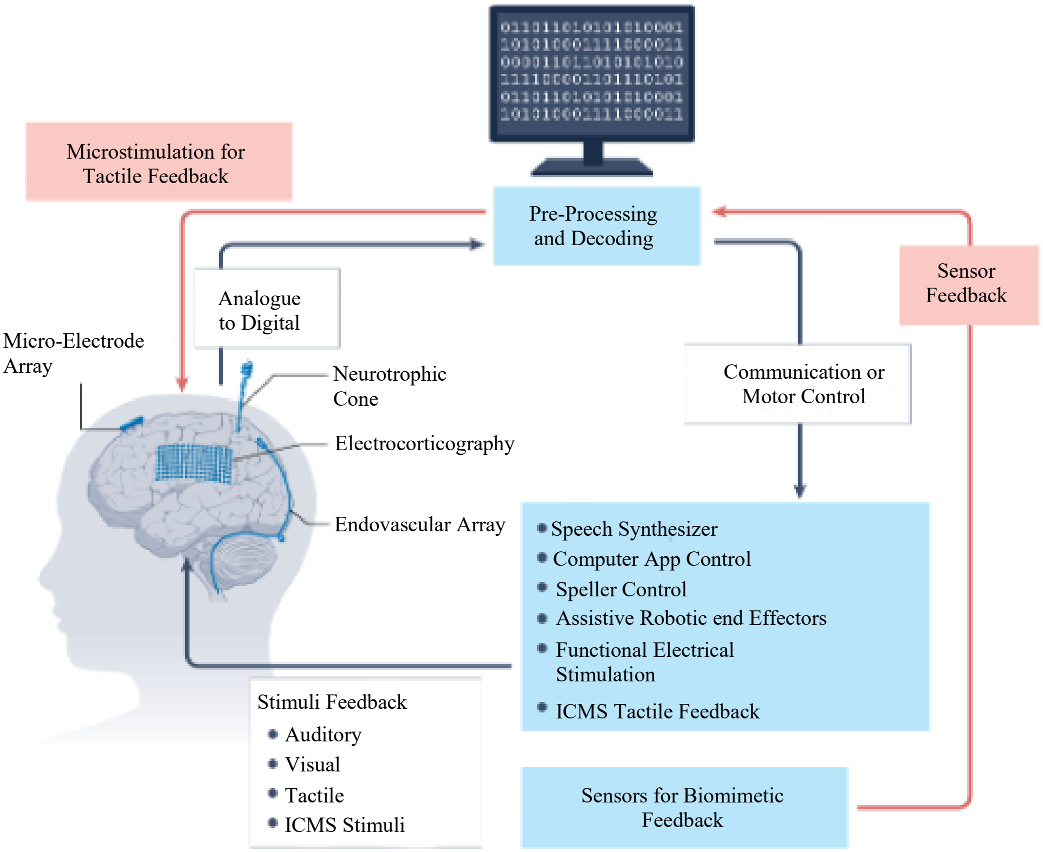

Figure 1. Closed-loop brain–machine interface for neural recording, control, and feedback.

BACKGROUND & EVOLUTION OF NEURAL IMPLANTS

History of BCI

The integration of neuroscience and artificial intelligence [AI] has been a transformative journey, reshaping our understanding of brain function and cognitive processing. This interdisciplinary field originated in the mid-20th century, when researchers began investigating how biological neural networks could guide the development of artificial intelligence. An early milestone was the McCulloch–Pitts neuron model, which established the basis for artificial neural networks by mathematically imitating brain-like processing [8].

As neuroscience advanced, discoveries, such as DNA sequencing and brain imaging technologies, like fMRI, provided deeper insights into brain function, fueling AI research. This led to the development of brain-inspired architectures, including convolutional and recurrent neural networks, which mimic the brain's visual and temporal processing systems [9].

AI has significantly empowered neuroscience by enabling real-time neural decoding, improving brain–computer interfaces [BCIs], and automating diagnostics through machine learning applied to neuroimaging [10]. These advancements have fueled breakthroughs in adaptive BCIs, allowing individuals with paralysis to control prosthetics using neural signals, restoring mobility and independence [9].

Despite these achievements, challenges remain, including data integration issues, ethical concerns, and the "black-box" nature of AI systems, which make neural decision-making difficult to interpret [10]. However, the synergy between AI and neuroscience continues to drive innovations in dynamic connectivity mapping, personalized medicine, and closed-loop brain–computer systems that adaptively respond to neural states [10].

The First Successful Mind-Controlled Device

The first successful mind-controlled device was a mind-controlled robotic arm developed by researchers at Carnegie Mellon University in collaboration with the University of Minnesota. This breakthrough was achieved using a noninvasive brain–computer interface [BCI], allowing users to control the robotic arm purely through thought without requiring brain implants [11].

This innovation was particularly significant because previous BCIs relied on invasive brain implants, which required surgical procedures and posed risks. The noninvasive approach used advanced neural decoding and machine learning techniques to interpret brain signals, enabling real-time continuous control of the robotic arm [12].

This development has major implications for individuals with paralysis and movement disorders, as it opens the door for accessible, noninvasive neuroprosthetics that could improve mobility and independence [13].

MAJOR BREAKTHROUGH OF BRAIN–COMPUTER INTERFACE

Elon Musk's Neuralink

The company Neuralink was founded by Elon Musk in 2016 [2]. It seeks to create high-bandwidth interfaces to improve human abilities and help manage neurological disorders. Their vision involves implanting ultrafine electrodes directly into the brain to establish a seamless connection between neural activity and external devices. Neuralink utilizes technological electrodes, called "threads," which are inserted into the brain using surgery. These threads are engineered to accurately detect and record neural signals. The signals are then processed by a small, implantable device known as the "Link," which wirelessly communicates with external devices for data analysis and interpretation as shown in (Figure 2).

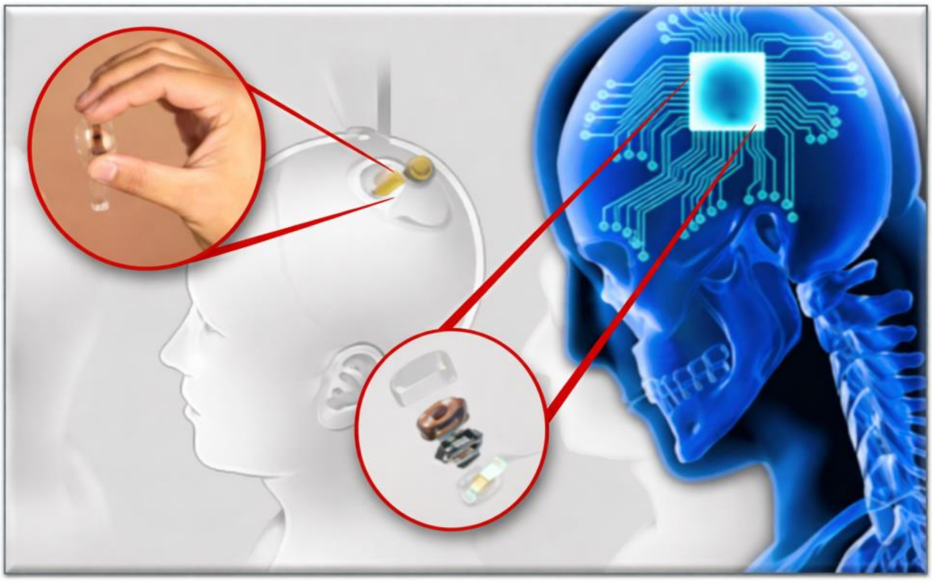

Figure 2. Neuralink's application and other therapeutic applications of BMIs.

- *Spinal Cord Injury:* Neuralink enables individuals with spinal cord injuries to regain movement by directly linking the brain to prosthetic limbs, effectively bypassing the damaged spinal cord. This allows anyone to control their movements and feel sensory feedback, like touch and pressure, just like they would with their natural limbs. The most appropriate example for this is of Sir Gert-Jan Oskam [3]. Who met with an accident and Neuralink helped the most. He can now walk independently and even climb stairs without assistance. This is the power of Neuralink, which makes any paralyzed person walk and run. In fact, it gives them another life to live.

- *Neurological Disorders:* Neuralink may offer new treatment options for neurological disorders such as Parkinson's disease, epilepsy, and Tourette syndrome. Neuralink could potentially reduce symptoms and enhance the quality of life for individuals with such conditions by modulating neural activity and delivering precise stimulation to targeted brain regions. When brain excitation increases, inhibitory synapses act to suppress and regulate the activity of other neurons.
- *Stroke Rehabilitation:* Neuralink may support stroke rehabilitation by promoting neural retraining and neuroplasticity. The brain–machine interface (BMI) can help restore motor function and improve recovery through targeted stimulation.
- *Depression:* Depression is one of the most common mental health disorders, and nearly one-third of cases are resistant to treatment. Brain–machine interface (BMI) therapies offer hope for patients who do not respond to medications. Unlike drugs, which act on the entire body, BMIs can precisely target specific brain regions. Although BMIs may also produce side effects, they are likely to be less severe than those associated with medications.

CURRENT STATE OF NEURAL TECHNOLOGY

How Far Are We from Fully Functional Brain Implants?

The development of fully functional brain implants has advanced significantly, yet key challenges remain before they can be widely adopted. "Despite significant advancements in neuroengineering, fully functional brain implants capable of seamless bidirectional communication with the nervous system remain in early experimental stages, with challenges in long-term stability and neural integration" [14].

While deep brain stimulation and neuroprosthetics show promise, "current brain implant technologies, including deep brain stimulation and neuroprosthetics, have demonstrated promising results, but widespread clinical adoption of fully autonomous implants is still hindered by limitations in biocompatibility and signal fidelity" [15]. Some experimental models have shown early success, but "while scaffold-based neural implants show potential for neuroregeneration, existing models struggle to replicate the complexity of natural brain networks, preventing full restoration of lost function" [16].

Who Is Funding Human Trials?

According to research, funding is largely driven by industry with support from government bodies. In neuroprosthesis research and development, it is important to clarify in advance who will handle technical maintenance after a study ends and whether the device will remain available to the patient once the trial is completed or discontinued.

THE PROMISE OF INTELLIGENCE ENHANCEMENT

How Neural Implants Could Boost Human Abilities

Extension of Human Memory

Brain signals can be converted into information that represents human intention may be useful for behavior and trait research. The legal and ethical problems raised by these applications are still largely unknown.

Telepathy Communication

BCI and CBI enable non-physical communication methods. The field of brain–brain interface research is still in its infancy. The application of telepathy in science and engineering may grow in the future.

Automation and Control

BCI has growing relevance in automation and control industries. It helps physically challenged individuals automate home activities. Future developments may bring positive impacts in industrial manufacturing.

Intelligence Sharing

Although it may sound like science fiction, the underlying principles of this technology suggest that the brain could potentially be artificially reprogrammed. However, reaching this stage requires a thorough understanding of brain structure and function, which current knowledge has not yet fully achieved.

Localized Brain–Computer Interface

A large volume of signals and background noise is captured even for a single intended task, making processing difficult. By localizing the BCI system, specific signals responsible for controlling a targeted body part can be recorded. For instance, in a person with speech impairment, placing the BCI in a brain region involved in speech control could enhance system performance and potentially reduce its size.

CHALLENGES AND POTENTIAL RISKS

Security

Advances in brain–computer interfaces create the risk of cyberattacks that could disrupt normal system operation. Attackers might modify commands generated by the feature-translation component, potentially causing harmful effects to the user. Therefore, researchers must identify vulnerable BCI components and develop strong security measures to protect them.

Ethical and Legal Concerns

Concerns are mainly associated with invasive BCIs. Since they are implanted into brain tissue, they may damage neurons and blood vessels and increase the risk of infection. Moreover, the body's immune system may recognize the implant as a foreign object and reject it.

Convenience and Flexibility

Most BCI systems require calibration data to correct changes resulting from neural plasticity or slight movements of the electrode arrays. This often leads to frequent retraining of the decoder, which is inconvenient, time-consuming, and burdensome for the user.

Battery Lifetime

However, the warm, fluid environment of the brain affects the implants' ability to retain power. The cerebrospinal fluid, a strong solvent, slowly corrodes the electrode insulation, which can eventually cause short circuits and increase cross-talk between electrodes. This issue shortens battery life and limits the number of signals the electrodes can record.

FUTURE WORK

- *Expanding AI-Driven Security Measures:* Further investigation into cutting-edge encryption techniques to prevent unauthorized access to brain data.
- *Improving Signal Processing Accuracy:* Next-generation neural decoding models are being created to increase accuracy and reduce misunderstandings.
- *Standardization & Regulatory Approval:* Strict ethical guidelines for the use of BCI are being developed in collaboration with government agencies and medical boards.
- *Analyzing Non-Invasive Technologies:* Enhancing minimally contact neural interfaces for non-medical applications.
- *Improving the User Experience:* BCIs will be simpler for everyday users to comprehend if interfaces are created that can be tailored to specific brain patterns.

CONCLUSION

Although studies on fully functional implants are still in their early stages, the combination of neuroscience and artificial intelligence [AI] has produced developments in neural implants and brain–computer interfaces [BCIs]. Although deep brain stimulation is encouraging, ethical issues and long-term stability continue to be problems. Industry-led funding and research projects encourage human trials so that these technologies may be used in medical and cognitive applications. Striking a balance between innovation and ethical governance, these neurotechnologies could transform human enhancement, rehabilitation, and cognition. That would start a new age.

REFERENCES

1. van Stuijvenberg OC, Broekman MLD, Wolf SEC, Bredenoord AL, Jongsma KR. Developer perspectives on the ethics of AI-driven neural implants: A qualitative study. Sci Rep. 2024;14(1):7880. doi: 10.1038/s41598-024-58535-4.
2. Maiseli B, Abdalla AT, Massawe LV, Mbise M, Mkocha K, Nassor NA, et al. Brain–computer interface: Trend, challenges, and threats. Brain Inform. 2023;10:20. doi: 10.1186/s40708-023-00199-3.
3. Valeriani D, Santoro F, Ienca M. The present and future of neural interfaces. Front Neurorobot. 2022;16:953968. doi: 10.3389/fnbot.2022.953968.
4. Musk E, Neuralink. An integrated brain–machine interface platform with thousands of channels. J Med Internet Res. 2019;21(10):e16194.
5. Singh SY. Review paper on BCIs. Int J Eng Res Technol. 2015;Conv3(IS10):102. doi: 10.17577/IJERTCONV3IS10102.
6. Peksa J, Mamchur D. State of the art on BCI technology. Sensors (Basel). 2023;23(13):6001. doi: 10.3390/s23136001.
7. Onciul R, Tataru CI, Dumitru AV, Crivoi C, Serban M, Covache-Busuioc RA, et al. Artificial intelligence: Transformative synergies in brain research. J Clin Med. 2025;14(2):550. doi: 10.3390/jcm14020550.
8. Tekin U, Dener M. A bibliometric analysis of studies on AI in neuroscience. Front Neurol. 2025;16:1474484. doi: 10.3389/fneur.2025.1474484.
9. Li PH, Lee JCK. AI, brain, and child: Navigating the intersection of AI and neuroscience. AI Brain Child. 2025;1:3. doi: 10.1007/s44436-025-00004-4.
10. Carnegie Mellon University. Robotics Institute [Internet]. Pittsburgh (PA): Carnegie Mellon University; [cited 2026 Feb 11]. Available from: https://www.ri.cmu.edu/
11. TechBriefs. Emerging technologies in AI and neuroscience [Internet]. [cited 2026 Feb 11]. Available from: https://www.techbriefs.com
12. Carnegie Mellon University. Machine Learning Department [Internet]. Pittsburgh (PA): Carnegie Mellon University; [cited 2026 Feb 11]. Available from: https://www.ml.cmu.edu
13. Bhat VB. Brain implants: An overview on the advancements and neuroethics. J Neurosurg. 2015;123(4):1026–1032. doi: 10.3171/2015.7.JNS151026.
14. Singh S. Exploring the potential of brain implants. J Neurosci Neuropharmacol. 2023;9(1):189. doi: 10.4172/2469-9780.2023.9.1.189.
15. Shimba K, Chang CH, Asahina T, Moriya F, Kotani K, Jimbo Y, et al. Functional scaffolding for brain implants. Front Neurosci. 2019;13:890. doi: 10.3389/fnins.2019.00890.
16. Raspopovic S, Ienca M, Valle G. Advances and challenges in brain implant technology. Lancet Digit Health. 2025;7(1):e1–e10.