

3. Neurotechnology- Science & Technology

Neurotechnology will soon deepen understanding of the brain and may even allow it to influence its functioning

Neurotechnology

Neurotechnology refers to a broad set of tools, systems, and techniques designed to directly interact with the nervous system, particularly the brain, by recording, decoding, stimulating, or modulating neural activity.

Its core objective is to understand brain function, restore lost neurological capabilities, and potentially enhance cognitive or motor performance.

A central pillar of neurotechnology is Brain-Computer Interfaces (BCIs), which establish a direct communication pathway between neural signals and external devices.

BCIs translate electrical or metabolic brain signals into machine-readable commands, enabling control of devices such as computer cursors, wheelchairs, speech synthesizers, or robotic limbs.

BCIs can be-

1. Non-invasive (EEG, fNIRS), which are safer but offer lower signal resolution.
2. Invasive (implanted electrodes), which provide high precision but raise surgical and ethical concerns.

Current applications are predominantly therapeutic and assistive, including neurodiagnostics, neuroprosthetics, and neuromodulation therapies.

BCIs are being explored for conditions such as paralysis, spinal cord injuries, Parkinson's disease, epilepsy, major depressive disorder, and locked-in syndrome.

Experimental studies have demonstrated brain-to-brain communication in animals, but human applications remain restricted to clinical and research contexts.

Future possibilities—cognitive enhancement, behavioural modulation, or military uses—raise profound ethical, legal, and societal concerns.

Benefits and Rationale for Neurotechnology in India

India faces a rapidly rising neurological disease burden, driven by population ageing, non-communicable diseases, road accidents, and lifestyle-related mental health disorders.

Stroke-related disabilities, spinal injuries, Parkinson's disease, epilepsy, and depression impose high long-term healthcare and productivity costs.

Neurotechnology offers transformative clinical solutions, such as-

Neuroprosthetics enabling paralysed individuals to regain movement, grasping ability, or communication.

Deep brain stimulation and non-invasive neuromodulation reducing dependence on long-term pharmacological treatment in psychiatric and neurological disorders.

From an economic and strategic perspective, neurotechnology aligns with India's comparative strengths in- Biotechnology and life sciences. Engineering, electronics, and materials science. Artificial intelligence, data science, and signal processing.

The sector has strong potential to generate high-value intellectual property, medical devices, and skilled employment, supporting India's transition to a knowledge-driven economy.

India's Progress in Neurotechnology

Indian academic and research institutions are increasingly contributing to applied neurotechnology research.

IIT Kanpur has developed a BCI-powered robotic hand aimed at helping stroke patients regain motor function through neural signal decoding.

Advanced neuroscience research is underway at the National Brain Research Centre, which focuses on brain disorders, cognition, and translational neuroscience.

The Indian Institute of Science Brain Research Centre contributes to foundational research in neural circuits, brain mapping, and computational neuroscience.

Indian startups are beginning to explore unconventional neurotechnology applications— For example, Dognosis is analysing dog brain signals to detect cancer-related scents, demonstrating the potential of animal-focused neurotech as a precursor to human diagnostic tools. Despite these advances, India's neurotechnology ecosystem remains fragmented, with limited clinical translation and commercial scale-up.

Global Status of Neurotechnology

The United States leads global neurotechnology development, supported by large-scale public funding and private investment.

The NIH BRAIN Initiative plays a central role in advancing brain mapping, neural recording tools, and translational neurotechnology.

In 2024, Neuralink received regulatory approval for human trials, demonstrating that implantable BCIs can help paralysed patients regain limited motor control.

China's Brain Project (2016–2030) integrates cognition research, brain-inspired artificial intelligence, and neurological disease treatment, reflecting a strong state-driven model.

The European Union and Chile are global pioneers in neurorights legislation, focusing on—

1. Mental privacy and protection of neural data.
2. Cognitive liberty and freedom from non-consensual neural manipulation.
3. Safeguards against discrimination based on neural information.

Ethical, Legal, and Social Concerns

Neurotechnology raises novel ethical challenges that go beyond traditional biomedical regulation.

Key concerns include—

1. Neural data privacy, as brain signals may reveal thoughts, intentions, or emotional states.
2. User autonomy and informed consent, particularly for invasive BCIs and vulnerable populations.
3. Risk of coercion or misuse, including surveillance, behavioural control, or military exploitation.
4. Equity and access, as advanced neurotechnologies may widen health and social inequalities.

Existing health and IT laws are often inadequate to address the unique risks associated with direct brain–machine interaction.

Way Ahead for India

Neurotechnology offers India significant opportunities in healthcare delivery, rehabilitation, recreation, and the broader innovation economy.

India's genomic diversity, large patient base, and growing neuroscience talent pool provide a strong foundation for responsible innovation.

However, sustained growth requires a robust regulatory and governance framework, including—

1. Clear clinical trial and approval pathways for BCIs and neurodevices.
2. Data protection rules specifically addressing neural data and cognitive privacy.
3. Ethical review mechanisms tailored to invasive and enhancement-oriented neurotechnologies.

Public engagement is essential to build societal trust, ensuring informed debate on the benefits, risks, and acceptable limits of brain-interfacing technologies.

A balanced approach—encouraging innovation while safeguarding human dignity, autonomy, and rights—will be critical for India's neurotechnology future.

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