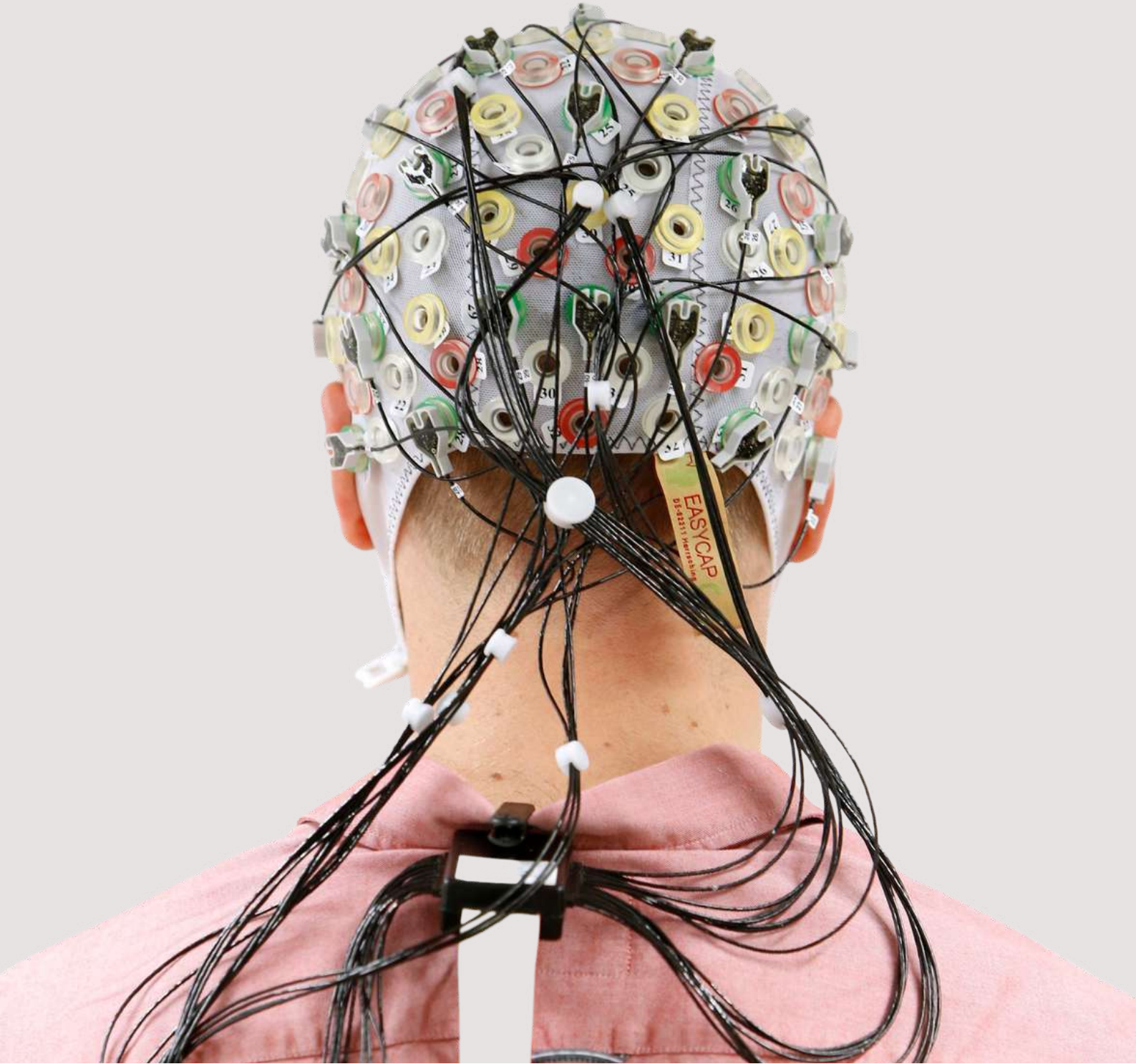
Market Analysis

NEUROTECHNOLOGY

March 2023

The Neurorights Foundation



Contents

Executive summary

This comprehensive market analysis is comprised of detailed information regarding the rapidly growing market of neurotechnology, an emergent sector of which covers the pioneering & development of Brain-Computer Interfaces (BCIs). The analysis provides up-to-date information on the current market size and growth rates over the next five years, as well as detailed profiles of the key players in the industry, including implantable or wearable BCI companies.

The next five years represent the beginning of a new age for technology; for the first time in history, we are facing the real possibility of human brain activity being measured and altered using neurotechnology.

> We define 'neurotechnology' as methods that measure and alter nervous system activity

What is unique about these methods is that they go to the core of what it means to be human. As we know, the brain is not just another organ. It is an organ that generates all of our mental and cognitive activity. All of our thoughts, perceptions, imagination, memories, decisions, and emotions are generated by the activity of the neural circuitry within our brains.

There are many different categories within neurotechnology, such as neuroprosthetics, neuromodulation, neurorehabilitation, or neurosensing. In this report, we will focus on brain-computer interfaces with an in-depth analysis of the markets of both implantable and non-implantable devices.

Why is neurotechnology important?

Neurotechnology has the potential to significantly advance our understanding of the brain and to develop new treatments for neurological and psychiatric disorders. Scientists around the world are developing neurotechnology that could lead to new therapies for mental illness and neurological diseases, such as Alzheimer's, schizophrenia, stroke, post-traumatic stress disorder, depression, or addiction.
Finally, companies and governments are developing devices that could potentially allow people to communicate by thinking, decode mental activity and commands by reading their brain data, and have brain interfaces access all the internet's databases and capabilities.

**The market analysis on Neurotechnology is provided for informational purposes only by the Neurorights Foundation and should not be construed as legal advice or endorsement.*

The Neurotechnology Industry

Governments are spending unprecedented public resources to advance medical, national security, and economic goals. Large companies and startups are investing to innovate, scale and win market share. Press reports and social media posts highlight the promise, profits and perils of neurotechnology both real and imagined.

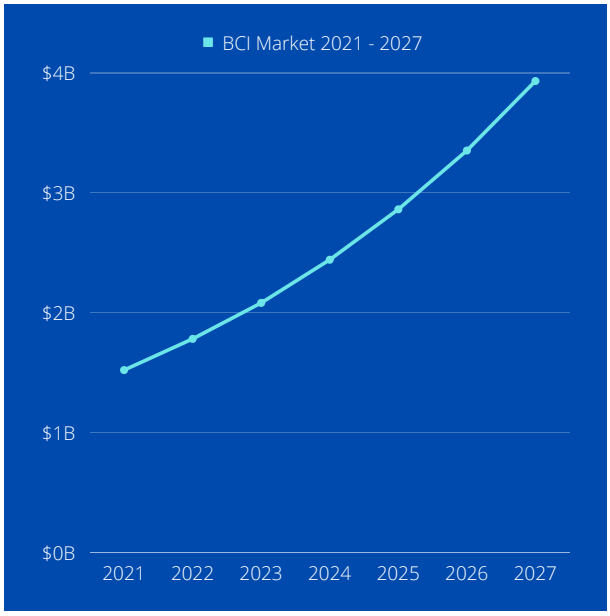
Market Projections

According to **NeuroTech Analytics**' recent report on neurotechnology, **the total investments in NeuroTech companies have increased 21 times over the last 10 years**, from $331 million to $7.3 billion. **The overall investment in NeuroTech companies amounts to $33.2 billion**, indicating that the industry is rapidly expanding and attracting substantial funding. [1]

Initiatives such as the **BRAIN Initiative** by the U.S. government and the **Human Brain Project** by the E.U. will make investments of **$6.6 billion** and **$1.19 billion euros**, respectively, in the coming years, according to **Strategic Market Research LLP**. [2]

China will be investing **$1 billion** until 2030 in the **China Brain Project**, and **Japan** will invest **40 billion JPY** in its Brain initiative. [2] In Canada, the **Canada Brain Research Fund** invested **267 million CAD** in 2021. [2]

Other Countries, such as Korea, Australia and Israel, are also taking part in the BRAIN Initiatives. [2]



According to Grand View Research, the global brain computer interface market size (not including BRAIN Initiatives) was valued at **$1.52 billion in 2021** and is anticipated to grow at a compound annual **growth rate (CAGR) of 17.16%.** [3] Based on this information, we calculated an **expected market value of $3.93 billion in 2027**. This indicates a significant growth potential for BCIs in the coming years.

1. Analytics.neurotech.com. (n.d.). Retrieved February 24, 2023, from http://analytics.neurotech.com/neurotech-investment-digest.pdf
2. Llp, S. M. R. (2022, July 6). Brain-computer interface market will attain a value of USD 5.34 billion by 2030.GlobeNewswire News Room. Retrieved October 27, 2022, from https://www.globenewswire.com/fr/news-release/2022/07/06/2475404/0/en/Brain-Computer-Interface-market-will-attain-a-value-of-USD-5-34-billion-by-2030.html
3. Brain Computer Interface Market Report, 2022-2030. (n.d.). Retrieved October 27, 2022, from https://www.grandviewresearch.com/industry-analysis/brain-computer-interfaces-market

Brain-Computer Interfaces

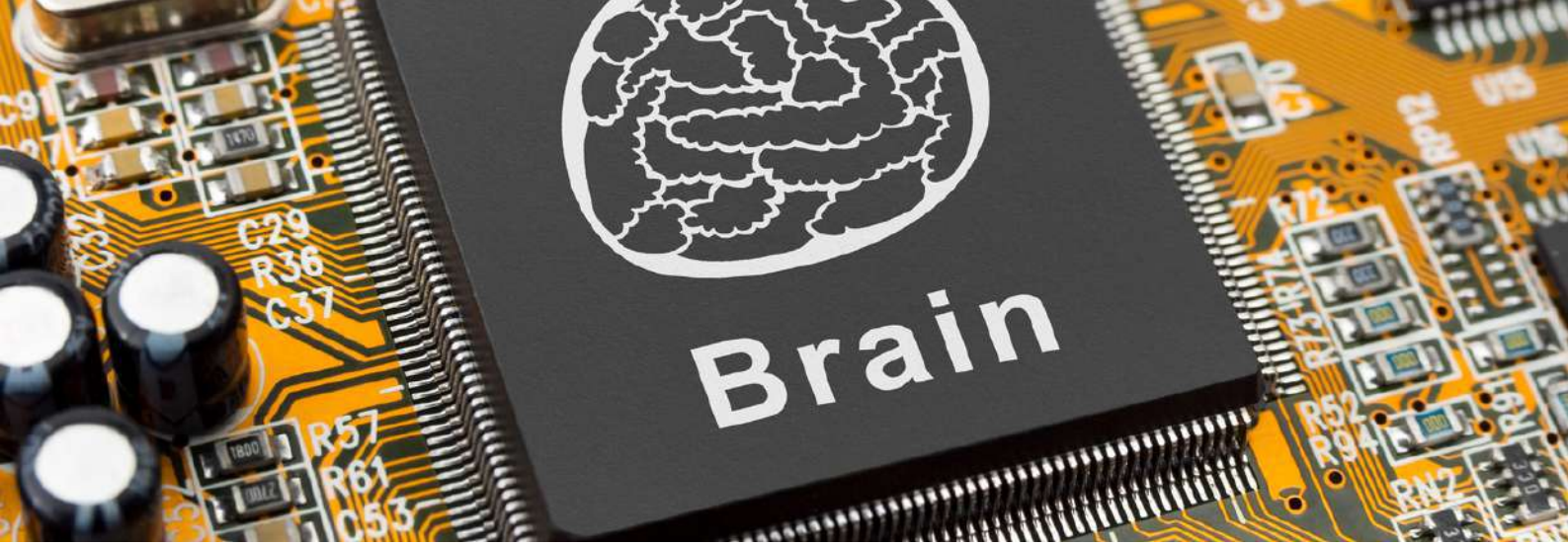
At the heart of neurotechnology are brain-computer interfaces ("BCIs")— devices that connect a person's brain to a computer or to another device outside the human body like a smartphone. BCIs allow bidirectional communication between the brain and the outside world, exporting brain data or potentially altering brain activity, and they can operate in two different ways. They can be either **implantable** (inside a person's skull) or non-implantable **wearables** (like a helmet worn over a person's head).

Funding Sources

BCIs have attracted a significant amount of funding in recent years. A large portion of funding for BCI companies comes from venture capital or private angels. According to our research, one of the largest VCs known to invest in such neurotechnology is **Khosla Ventures**, which invested in more than five of the current growing BCI companies, such as Kernel, Syncheron, Thync, Flow Neuroscience, and Neurotrack.

In addition to VCS, private investors are also investing in BCI. **Peter Thiel,** is a private investor/angel, who invested in both BlackRock Neurotech and NextMind. Furthermore, Companies such as **Microsoft** and **Johnson & Johnson** have also made investments in BCI neurotechnology. In addition, **DARPA**, The Defense Advanced Research Projects Agency, has been investing in various BCI companies, mostly implantable and for research purposes.

mindBEAGLE,
(Florian Voggeneder / Guger Technologies)



Within the neurotech industry, **the top-5 Brain-Computer Interface (BCI) companies by total investments** in 2021, according to Crunchbase and NeuroTech Analytics [4] [5]:

- **Neuralink** - $363 Million
  - Founded by Elon Musk, Neuralink is developing a high-bandwidth implantable device for brain-computer communication. The company's current focus is on developing a device that can allow users to control computers, smartphones, and other devices with their thoughts.
- **Kernel** - $107 million
  - Developing non-implantable wearable devices that stimulate brain activity to enhance cognition and treat neurological disorders. The company's current focus is on developing wearable devices that use near-infrared light to stimulate brain activity, with the aim of improving memory, attention, and other cognitive functions.
- **Blackrock Neurotech** - $10 million
  - Developing implantable devices for high-precision brain activity recording and stimulation, for research and treatment of neurological disorders.
- **Paradromics** - $58.3 million
  - Developing implantable devices for high-bandwidth communication between the brain and computers, with applications in brain-computer interfacing, neural prosthetics, and other areas.
- **Synchron** - $130 million
  - Developing an implantable device called the Stentrode, which can be inserted into the brain via the blood vessels, for controlling computers and treating neurological disorders such as paralysis.

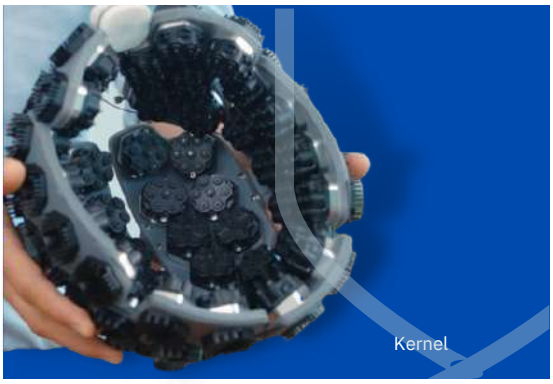
Overall, these companies are all focused on developing innovative BCI devices that can help treat neurological disorders and enhance brain-computer communication, with various approaches such as implantable and non-implantable devices using different types of stimulation.

Additional leading BCI Companies. Source: Neurotech Analytics [4]

4. Analytics.neurotech.com. (n.d.). Retrieved February 24, 2023, from http://analytics.neurotech.com/neurotech-investment-digest.pdf
5. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Wearables - Non-Implantable BCIs

Unlike implantable BCIs, a non-implantable BCI does not touch the brain; instead, it rests on a person's head. "Wearable" BCIs, such as helmets, glasses, and wristbands, can be used to predict a person's intended speech or movement. [6]
Wearable devices are currently dominating the BCI market. These devices could also help people with expressive or communicative conditions to communicate by decoding the images in a person's mind. Indeed, scientists have successfully shared images and words between two people in different rooms using non-implantable BCIs, effectively allowing the two to exchange thoughts. But non-implantable BCIs could do much more. They already have enabled a man who is quadriplegic to drive a Formula One race car. Besides using BCIs to decode neuronal activity, coupled with similar methods to the one described above—for recording and stimulating the brain—BCIs can be used to effectively control animals' movement. [6]



In addition to measuring and analyzing brain activity, wearable BCIs may one day be used to alter it.

Non-implantable procedures for studying the brain include:

- **EEG** (Electroencephalography): is a technique for measuring electrical activity in the brain from the scalp surface. The electrical current created by the brain is measured by electrodes placed on the scalp. EEG is the most commonly used because of the cost and hardware portability.
- **MEG** (Magnetoencephalography): MEG measures the magnetic field produced by brain currents and has a higher spatial resolution than EEG.
- **PET** (Positron Emission Tomography): It is a nuclear imaging technique used in medicine to study several processes in the body, including blood flow, metabolism, and neurotransmitters.
- **fMRI** (functional magnetic resonance imaging): In this, blood oxygenation or flow changes caused by brain activity are measured. It is a radiation-free technology that is simple to use. It has a good spatial, but poor temporal resolution.
- **fNIRS** (Functional near-infrared spectroscopy): NIRS (near-infrared spectroscopy) is used for functional neuroimaging. The hemodynamic responses associated with neuron behavior quantify brain activity using fNIRS.

Cost of wearable BCIs

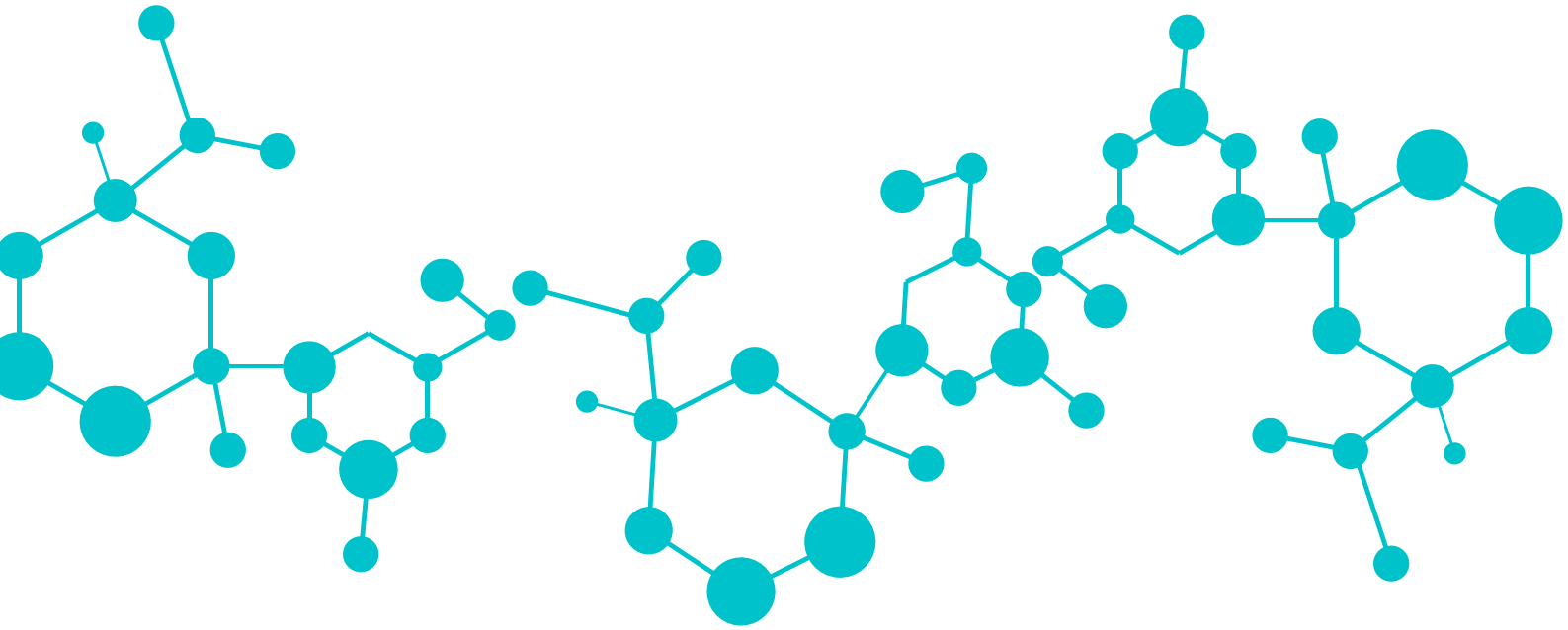
Low-cost EEG are below $350 for 24 electrodes. [7] According to research published in NCBI, BCIs have a high initial cost and the cost of ongoing technical assistance. Although most non-implantable BCI devices have low upfront costs (**$5,000-$10,000**), they require continuing technical assistance. [7]


BitBrain Versatile EEG

6 It's time for neuro - rights. CIRSD. (n.d.). Retrieved October 27, 2022, from https://www.cirsd.org/en/horizons/horizons-winter-2021-issue-no-18/its-time-for-neuro--rights
7, Base Year: 2021 |. (1970, May 25). Brain Computer Interface Market, growth trends: Report 2030. STRATEGIC MARKET RESEARCH. Retrieved October 21, 2022, from https://www.strategicmarketresearch.com/market-report/brain-computer-interface-market

Leading Non-Implantable BCI Companys

Company Name	Industry	Type	# of employees	Value [8]	BCI Products
Meta	• Technology • Social media • Consumer electronics • Virtual Reality	Public	83,553 (2022)	$165.988B (Net Worth)	FRL Wrist-band Wearable
Emotiv	• Neurotechnology • Brain-computer interfaces • bioinfomatics	Private	51-100 (2021)	Unknown to us	EPOC+ wireless headset that records EEG
Kernel	• Brain-computer interfaces • Neurotechnology	Private	51-100 (2022)	$107M (Funding)	Kernel Flow TD-fNIRS) system Wearable
Neurable	• Brain-computer interfaces • Neurotechnology	Private	1-10(2022)	$9.3M (Funding)	Enten Wearable EEG tracking headphones
MindMaze	• Brain-computer interfaces • Neurotechnology • Neurotherapeutic • Virtual Reality	Private	101-250 (2022)	$340.7M (Funding)	MindMotion™ PRO Brain Games
BrainCo	• Brain-computer interfaces • Neurotechnology	Private	11-50 (2022)	$6M (Funding)	Wearable wireless EEG brain wave detector



8. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Non-Implantable BCI Company Profiles

Meta (Facebook)

The American technology company, Meta Platforms, formerly known as Facebook, is based in Menlo Park, California. The company operates various products and services, including Facebook, Instagram, and WhatsApp. Meta is one of the world's most valuable companies and is considered to be a part of the "Big Five" American information technology companies, along with Alphabet, Amazon, Apple, and Microsoft. [9]

Facebook Reality Labs EMG Wristband

The Augmented Reality/Virtual Reality (AR/VR) department of Meta, Facebook Reality Labs (FRL), is developing a non-implantable interface for AR using Electromyography (EMG) wristbands. These wristbands will allow users to interact with FRL's AR glasses, potentially transforming the way people interact with each other. The wrist-based input is combined with usable but limited contextualized AI, which adapts to the user and their environment. [9]

Electromyography (EMG) is a technique that measures muscle activity by detecting the electrical potential generated by muscle cells during contraction. The signals generated by the muscles in the wrist are translated into digital commands that can be used to control the functions of a device. [9]

These signals enable highly personalized and adaptable control, with the ability to interpret finger motion as small as a millimeter. It may even be possible to sense the intention to move a finger. With sensors on the wrist, users will be able to interact with virtual objects or control the environment in a nearly frictionless manner. Additionally, individuals with congenital hand absence or limited hand function will be able to operate a virtual hand using the wristband. [9]

It is also expected that users of the wristband will be able to type at high speeds, potentially faster than with a traditional keyboard. [9]

Facebook Reality Labs has cost Meta $2.9 billion in Q1 2022 and $3.3 billion in Q4 2021, according to Business Insider. [10]

9. Jaloza, L. B. (2022, May 17). Inside facebook reality labs: Wrist-based interaction for the next computing platform. Tech at Meta. Retrieved October 21, 2022, from https://tech.fb.com/ar-vr/2021/03/inside-facebook-reality-labs-wrist-based-interaction-for-the-next-computing-platform/
10. https://www.businessinsider.com/meta-vr-ar-reality-labs-cutbacks-metaverse-2022-5

Kernel

Kernel is a neurotechnology company that specializes in developing brain-recording technologies. Its custom-built, non-implantable BCI acquires neural signals of a similar quality to functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), electrocorticography (ECoG), and electroencephalography (EEG). The company was founded in 2016 and is headquartered in Los Angeles, California. [11]

Many non-implantable methods for recording brain signals measure electromagnetic fields generated by groups of neurons or detect small changes in blood oxygenation, which correlate well to nearby neural activity. Kernel is building the next generation of brain measurement systems by leveraging the strengths of time-domain diffuse optical tomography (TD-DOT) into products that offer high-quality neural signals, full-head coverage, scalability, relatively low cost, natural environments, stimuli, and interactions, as well as freedom of user motion.

Kernel "Flow"

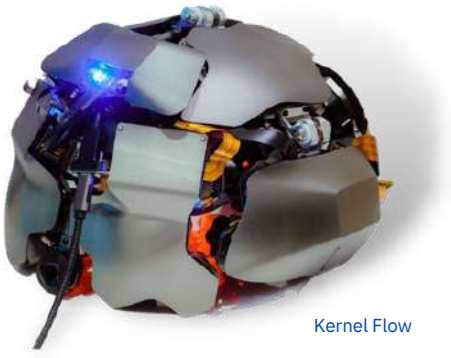
The Kernel Flow is a BCI wearable based on near-infrared spectroscopy (TD-NIRS) system that allows for natural head motion, a wide variety of stimuli and peripherals, various natural environments, and user interaction. NIRS uses infrared light to measure brain activity. The advantage of using light is that it is safe and works from outside the body, making it non-implantable and not requiring surgery to measure information. [11]

Kernel's device, the Kernel Flow, utilizes diffuse optical tomography (DOT) to measure brain activity. Specifically, a laser pressed against the scalp shines light into the head, which then travels through various layers of tissue, such as the skin, skull and brain. Some of the light is absorbed by the tissue while some of it is scattered back to the surface, and can be measured by the device. [11]

Kernel "Flux "

In addition to the Kernel Flow, the company has been developing another device, the Flux, which is a magnetoencephalography (MEG) headset, that is still in early stages of development.[11]

Kernel has raised a total of $107M in funding over 2 rounds. Their latest funding was raised on July 9, 2020, from a **Series C** round. Kernel is **funded by six investors:** Tiny Blue Dot, Manta Ray Ventures, **Bryan Johnson** (**Founder** of Kernel), General Catalyst, Eldridge, and **Khosla Ventures**.[12]



Kernel Flow

11. D'Anna, E. (2020, November 9). How kernel plans to put a brain-computer interface in every US home by 2033. Edoardo D'Anna's blog. Retrieved October 21, 2022, from https://edoardodanna.ch/article/kernel_flow_in_every_home_by_2033
12. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Emotiv

Emotiv is a bioinformatics company that specializes in the development of products and research related to the understanding of the human brain using electroencephalography (EEG). The company's product portfolio includes developments related to interactive television, everyday computer interactions, hands-free control systems, smart adaptive environments, art, accessibility design, market research, psychology, learning, medicine, robotics, automotive, transport safety, defense, and security. [12]

In June 2020, Emotiv Inc. launched the EPOC X, their most recent EEG headset. The device enables long and relevant neuroscience testing, and features a turning headband, simple hydrating sensors, and other capabilities. [12]

Emotiv EPOC X

In addition to the EPOC X, Emotiv has four additional non-implantable BCI products that are currently available for consumer purchase on their website. **These products range in price from $499 USD to $1699 USD.** [12] (see Table 1 for furter information)

The EPOC X headset, as well as the other devices offered by Emotiv, utilize a collection of non-implantable electrodes placed at various points around the skull to collect and read brain data, which is then translated into action on a computer or other device. The EPOC X specifically has 14 sensors, each of which is saline-moisturized to improve connectivity. Once attached to the head, the sensors detect brainwave activity associated with specific facial features, emotions, and thoughts. [12]

Emotiv's software allows for training of the device and the brain to work together to manipulate objects on the screen. Additionally, users can train the device to use their brainwaves to control on-screen keyboards, cursors, and real-world devices such as motorized wheelchairs or robotic arms. [12]

Emotiv has received funding from two main investors, Disney Accelerator and Techstars. T**he company has raised $120K** in funding on July 6, 2015, through a Pre-Seed round. **Their current funding amount is unknown to us.** [13]

12. EMOTIV. (2022, September 21). Retrieved October 21, 2022, from https://www.emotiv.com/
13. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Table 1: Emotiv BCI Products detection specifications

DESCRIPTION	INSIGHT 2.0	EPOC+	EPOC X	EPOC FLEX	MN8
Facial Expressions	Blink Wink Left/Right Furrow (frown) Raise Brow (surprise) Smile Clench Teeth (grimace)	Blink Wink Left/Right Look Left/Right Furrow (frown) Raise Brow (surprise) Smile Clench Teeth (grimace) Laugh Smirk Left/Right	Blink Wink Left/Right Look Left/Right Furrow (frown) Raise Brow (surprise) Smile Clench Teeth (grimace) Laugh Smirk Left/Right	Blink Wink Left/Right Look Left/Right Furrow (frown) Raise Brow (surprise) Smile Clench Teeth (grimace) Laugh Smirk Left/Right	TBA
Mental Commands	Neutral + up to 4 pretrained items from a list of 13 labels: Push Pull Lift Drop Left Right Rotate clockwise Rotate anti-clockwise Rotate forwards Rotate backwards Rotate left Rotate right Disappear	Neutral + up to 4 pretrained items from a list of 13 labels: Push Pull Lift Drop Left Right Rotate clockwise Rotate anti-clockwise Rotate forwards Rotate backwards Rotate left Rotate right Disappear	Neutral + up to 4 pretrained items from a list of 13 labels: Push Pull Lift Drop Left Right Rotate clockwise Rotate anti-clockwise Rotate forwards Rotate backwards Rotate left Rotate right Disappear	Neutral + up to 4 pretrained items from a list of 13 labels: Push Pull Lift Drop Left Right Rotate clockwise Rotate anti-clockwise Rotate forwards Rotate backwards Rotate left Rotate right Disappear	TBA

FEATURES	INSIGHT 2.0	EPOC X	EPOC FLEX KIT
-	$499	$849	$1699 +
Recording sensors	5 sensors	14 sensors	Up to 32 sensors
Sensor technology	Semi-dry polymer	Saline soaked felt	Saline/Gel
Refill mechanism	-	Yes	Saline only
Bluetooth®	Version 5.0	5.0 Ready	Version 4.0
Data quality	Good	Higher	Highest
Sensor locations	Fixed	Fixed	Configurable
Headband	Fixed position	Rotating	-
Set up time	1-2 min	3-5 min	15-30 min

EMOTIV. (2022, September 21). Retrieved October 21, 2022, from https://www.emotiv.com/

Neurable

Neurable is a neurotechnology company that specializes in the development of software utilizing advanced machine-learning techniques to classify the electrical signals produced by the brain in order to understand human intent. These biometric signals are then transformed into actionable insights for measuring emotions and providing control of connected devices.

The company claims that there exists a significant gap between the possibilities discovered in laboratory research and the products utilized in daily life, and aims to bridge this gap by converting brain research into practical products for general use.

One such product developed by Neurable is the non-implantable BCI device called Enten, which can be worn as a pair of headphones. Enten is the first pair of headphones capable of non-implantable BCI and aims to assist users in managing their time by suggesting break periods to maximize focus throughout the day. Additionally, the device incorporates both active controls to automatically silence notifications and passive controls to minimize distractions. [14]

The Enten headphones offer traditional headphone features along with the added benefit of providing the user with insight into their brain function. Neurable's goal with the Enten headphones is to create a feasible and relevant neurotechnology device for daily use, where similar devices have previously been unsuccessful. [14]

The addition of EEG sensors to everyday consumer tech, as demonstrated in the headphones, can provide valuable insights into one's working patterns. This development may pave the way for similar devices to offer insights into other areas of daily life, well-being, and self-awareness. For instance, smartwatches currently use heart rate data for various applications, such as health tracking, athletic performance, and meditation. The richness of brain data suggests that the potential applications are numerous and can be as diverse as the individuals who use them. [14]

Neurable has raised a total of $9.3 million in funding over 8 rounds, with the most recent funding being raised on September 1, 2021, from a Series A round. 14 investors have funded Neurable, with the most recent investors being **Fady Hannah-Shmouni, MD FRCPC and TRAC.** According to PrivCo, as of December 17, 2019, **Neurable has a post-money valuation in the range of $10 million to $50 million.** [15]

14. Freight, S. (n.d.). Neurable. Retrieved October 21, 2022, from https://neurable.com/blog/neurable-2021-annual-report
15. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

BrainCo

BrainCo is a company that was founded in 2015 by **Bicheng Han, a PhD candidate at Harvard Center of Brain Science**. It is a brain-computer interface (BCI) company that develops products and services for various markets, including personal health and well-being, robotic prosthetics, and STEM education, and has gained recognition on a global scale.

Focus1 BCI headband

he **Focus1**, also known as the **Fu Si headband**, is a product that claims to measure students' attentiveness by using electrodes to detect electrical activity in their brains. The data is then sent to teachers' computers or a mobile app. The headband also features a light that displays different colors, such as red, yellow, or blue, which allegedly indicate a child's level of engagement in the task, with red indicating the highest level of attention. In April 2021, the product caused concerns when photos and videos of primary school students in a Chinese province wearing the headbands surfaced online. [14] Currently, the product is available for purchase on several e-commerce sites for approximately **3,200 to 14,000 yuan (about $450-$2000)**. [16]

Focus1 BCI headband

The headband's advertisement on e-commerce retailer JD.com. The colors of the light on the band indicate different levels of concentration, with red showing the highest level.

In addition to Focus1, BrainCo has launched a new initiative called the Cambridge StarKids Autism Rehabilitation Center, which involves a non-implantable EEG headband and computer-based games, activities, and exercises to provide a unique autism intervention. When combined with other behavioral therapies, this system enables therapists to gain real-time insights into an individual's brain activity, monitor their progress, and develop a better understanding of their abilities. It helps individuals develop skills such as social interaction, recognizing facial expressions, and maintaining eye contact. [16]

BrainCo has raised a total of $6M in funding over 3 rounds. [17] Their latest funding was raised on Dec 14, 2016 from a Seed round. BrainCo is funded by 5 investors. [17] **Startupbootcamp Digital Health Chengdu and Boston Angel Club** are the most recent investors. [17] **BrainCo has a post-money valuation in the range of $10M to $50M** as of Dec 14, 2016, according to PrivCo. [17]

16. BrainCo. (2021, December 9). Brainco begins clinical trials of innovative autism intervention based on brain-computer interface (BCI) technology. BrainCo begins clinical trials of innovative autism intervention based on Brain-Computer Interface (BCI) technology. Retrieved October 21, 2022, from https://www.prnewswire.com/news-releases/brainco-begins-clinical-trials-of-innovative-autism-intervention-based-on-brain-computer-interface-bci-technology-301441761.html
17. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

MindMaze

MindMaze is a company that was established in 2012 and specializes in brain technology and digital neurotherapeutics solutions for brain health and recovery on a global scale. Its mission is to facilitate the brain's recovery, learning, and adaptation abilities. The company operates through two core divisions, Healthcare and Labs, which work together at the convergence of neuroscience, bio-sensing, engineering, mixed reality, and artificial intelligence.

MindMaze Healthcare is developing a universal platform for brain health, which includes innovative solutions for neurology problems such as stroke, Parkinson's disease, and Alzheimer's disease. The company's R&D innovation hub, MindMaze Labs, is dedicated to the future of human computing and collaborates across multiple industries to develop and innovate the next generation of BCIs.

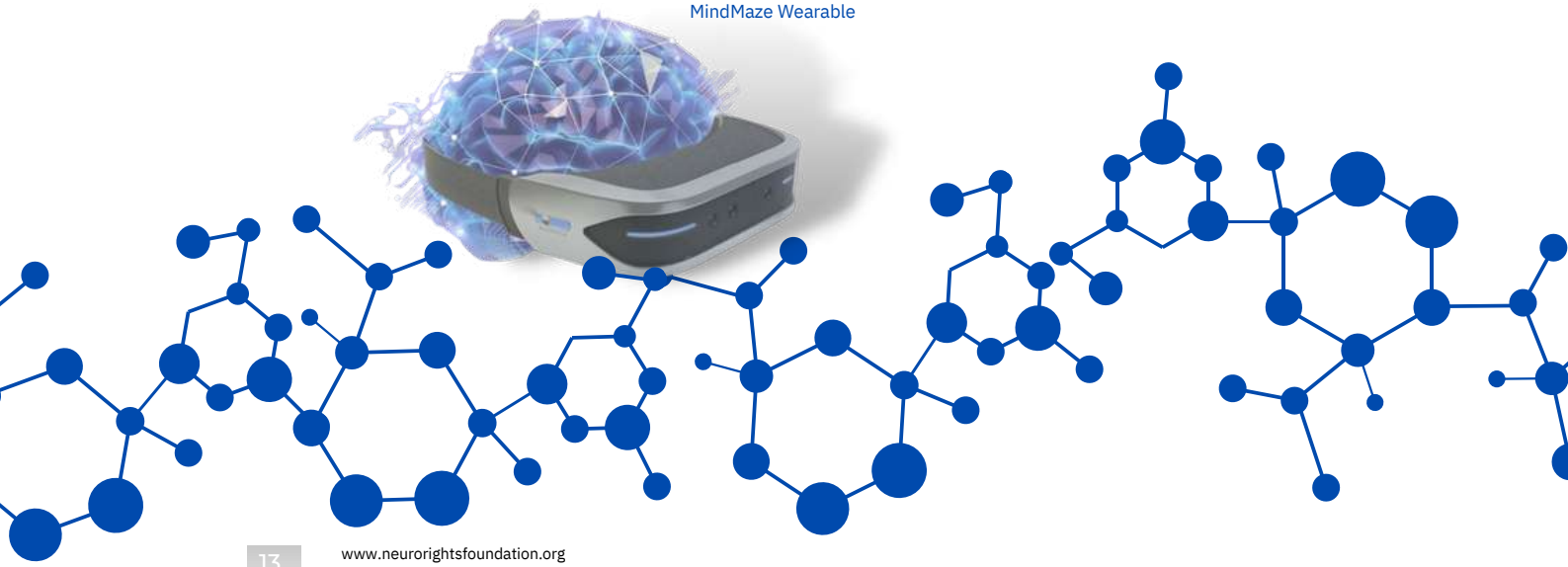
MindMaze provides game-like therapies and assessment tools for the rehabilitation and treatment of neurodegenerative diseases and brain injuries. [18]

MindMotion Go

Its MindMotion Go platform, which was cleared by the FDA in 2018, provides at-home physical therapy to improve motor skills. The company's MindMotion Pro system, designed for in-hospital use, received the FDA greenlight in 2017.
It also has products like MindPod, which focuses on motor skills and cognitive function, and TOAP Run for people with Parkinson's disease. [18]
The neurotherapy company **MindMaze is back by by Hollywood actor Leonardo DiCaprio** and has secured **$105 million** in financing. The company had previously announced raising **$125 million** a few months earlier. [19]

It is valued at more than **$1.5 billion** after receiving financing from **AlbaCore Capital Group** during their last round of funding. [18] According to Crunchbase, the company's total raise is now more than **$340 million**. [19]

MindMaze Wearable

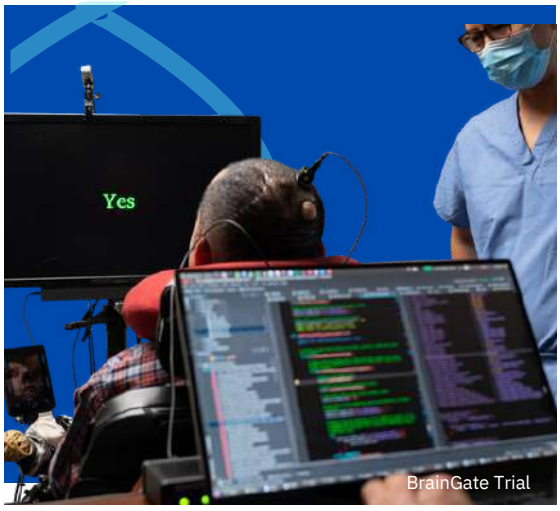


18. Digital neurotherapeutic startup Mindmaze raises $105M. MobiHealthNews. (2022, February 18). Retrieved October 21, 2022, from https://www.mobihealthnews.com/news/digital-neurotherapeutic-startup-mindmaze-raises-105m
19. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Implantable Brain-Computer Interfaces

Unlike non-implantable wearables, some BCIs are implantable and require surgery to place electrodes directly into a person's brain. The electrodes send brain data to a computer, where it can be analyzed and decoded. Implantable BCIs are nothing new and have been used in medicine for years; some familiar examples of implantable BCIs are cochlear implants or deep brain stimulators, which can help people with Parkinson's disease regain mobility.

Scientists have also shown how implantable BCIs can help people with missing or damaged limbs feel the heat and cold through their prostheses. For example, a person with Amyotrophic Lateral Sclerosis (ALS) who was implanted with a BCI developed by **BrainGate**, and previously could not speak or move, can now write and send emails, Google random questions, and shop on Amazon. [20]



BrainGate Trial

It is expected that in the coming years, BCIs might be able to provide active visual prostheses for blind patients, which would enhance their ability to sense proximity to the world around them.

Although there have been many remarkable applications in medicine, implantable BCIs can be used in other ways. For instance, in 2018, the **MIT Media Lab** used an implantable BCI to transcribe human thoughts into typed messages. Additionally, **Neuralink**, owned by Elon Musk, is developing a wireless implantable chip that can connect human brains to computers to enhance cognitive abilities through AI. Researchers have also found ways to use implantable BCIs to control the movements of laboratory animals, such as mice.

During a mouse's activity, such as eating, the BCI collects data from its brain. Scientists can utilize this data to trigger and stimulate the same brain regions that were previously recorded, resulting in the mouse repeating the same action, even if it had no intention to do so. Similar methods have also been applied to implant artificial memories or images into a mouse's brain, which can generate hallucinations and false memories of fear that are difficult to differentiate from reality. [21]

20. Fan, S. (2019, February 12). Paralyzed patients can now control Android tablets with their minds. Singularity Hub. Retrieved October 27, 2022, from https://singularityhub.com/2018/11/28/paralyzed-patients-can-now-control-android-tablets-with-their-minds/
21. It's time for neuro - rights. CIRSD. (n.d.). Retrieved October 27, 2022, from https://www.cirsd.org/en/horizons/horizons-winter-2021-issue-no-18/its-time-for-neuro--rights

Leading Implantable BCI Companys

Company Name	Industry	Type	# of employees	Value [22]	BCI Products
Medtronic	Medical devices	Public	95,000+ (2022)	$112.31B (Net Worth)	Multiple implantable devices Neuromodulation DBS technology
Johnson & Johnson	• Pharmaceutical • Medical devices • Consumer Healthcare	Public	144,500 (2021)	$435.44B (Net worth)	Multiple implantable devices
Neuralink	• Brain-computer interfaces • Neuroprosthetics	Private	300 (2022)	$363M (Funding)	The "Link" Implatable device
Synchron	• Brain-computer interfaces • Neuroprosthetics	Private	11-50 (2022)	$50M (Funding)	The Stentrode Implantable device Neuromodulation
Blackrock Neurotech	Brain-computer interfaces	Private	101-250 (2022)	$10M (Funding)	Multiple implantable devices Precision electrode technology
Paradromics	Brain-computer interfaces	Private	50(2022)	$58.3M (Funding)	Multiple implantable devices
BrainGate	Brain-computer interfaces	Private	Unknown to us	Unknown to us	"BrainGate" System Implantable device
GSK	Pharmaceutical	Public	94,000 (2022)	$63.55B (Net Worth)	Multiple implantable devices

22. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Implantable BCI Company Profiles

Medtronic

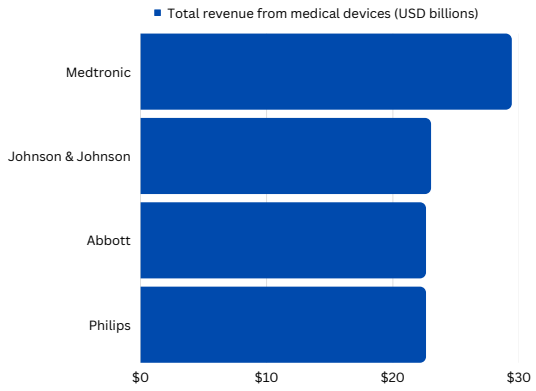
Medtronic is a medical device company recognized as the largest in the world. It employs over 90,000 people and operates in 150 countries, specializing in cutting-edge medical technology. **In 2022, Medtronic made $30.12B in revenue.** [23]

Medtronic focuses on the production and promotion of devices in various fields, such as cardiac rhythm disease, spine and biologics, cardiovascular, neuromodulation, diabetes, and surgical technologies. This includes devices for conditions related to the ear, nose, and throat (ENT) diseases, as well as cranial, spinal, and neurologic conditions. [23]

Areas of focus:

- BCI Categories: Open-Loop Efferent, Open-Loop Afferent
- Neurosensing Technique(s): EEG
- Neurostimulation Technique(s): DBS, PNS

The company produces both non-implantable and implantable hardware and makes tools for medical diagnosis and treatment through body/mind state interpretation and/or neurostimulation therapies. [24]



In this report, we will only focus on Medtronic's neuromodulation department. Specifically, we will discuss **the Medtronic Activa® PC neurostimulator.**

Neuromodulation

Neuromodulation is a department within Medtronic and is the third-largest department, having been established as the second-oldest. The department's product line includes neurostimulation systems and implantable drug delivery systems that target chronic pain, common movement disorders, as well as urologic and gastrointestinal disorders. Neuromodulation is a technique that involves the application of electrical signals to the nervous system. It is utilized as a treatment option for the management of chronic pain and/or movement disorders that are challenging to manage. **In 2014, the department's revenues amounted to $1.9 billion, which accounted for 11% of Medtronic's total revenues.** [24]

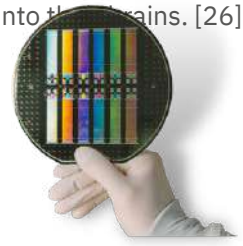
The Activa® PC is a DBS device that has the distinctive capability of providing stimulation to both hemispheres of the brain with a single device. It is equipped with a non-rechargeable battery and microelectronic circuitry that enables controlled electrical impulses to be delivered precisely to specific regions of the brain. The device is usually implanted subcutaneously near the clavicle and connected to an extension and leads that are placed in the brain. [25]

23. Anderson, C. (2021, December 28). Top 10 medical device companies in the World in 2022. Breaking Into Device. Retrieved October 21, 2022, from https://www.breakingintodevice.com/blogs/medical-sales/top-medical-device-2022
24. Medtronic. (n.d.). Products for healthcare professionals. Medtronic. Retrieved October 21, 2022, from https://www.medtronic.com/us-en/healthcare-professionals/products.html
25. Activa_pc_neurostimulator [operative neurosurgery]. (n.d.). Retrieved October 21, 2022, from https://operativeneurosurgery.com/doku.php?id=activa_pc_neurostimulator

Neuralink

Neuralink is a neurotechnology company that specializes in the development of implantable BCIs. The company was co-founded by **Elon Musk**, Max Hodak, and Paul Merolla. Neuralink was established in 2016, and its public disclosure first surfaced in March 2017.

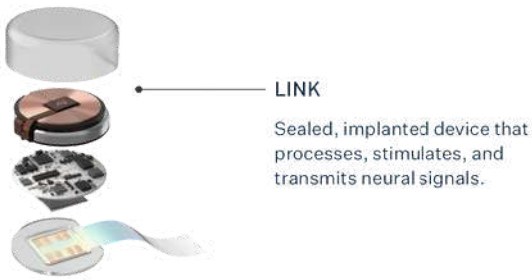
By July 2019, Neuralink had garnered a total of $158 million in funding, out of which $100 million was contributed by Musk. The company had a workforce of 90 employees at that time. [26] During that period, Neuralink had unveiled plans to develop a "sewing machine-like" device that could implant ultra-thin threads (measuring 4 to 6 µm in width) into the brain. In addition, the company demonstrated a system that could extract data from a laboratory rat via 1,500 electrodes. Although initial projections had suggested the company would commence human experiments in 2020, which has then been postponed to 2022. However, **the Food and Drug Administration denied a human-trials application** in early 2022, citing dozens of concerns about the company's device that employees are still working to address, according to a report by Reuters. Neuralink currently conducts tests on live animals such as monkeys, and pigs, by surgically implanting the devices into the brains. [26]



The company has raised a total of **$373 million in funding over 5 rounds**. [26] Their latest funding was raised on Jul 14, 2022 from a Secondary Market round. [26]

The "Link"

Neuralink is developing a neural implant known as the "Link", which is intended to allow users to control a computer or mobile device from any location. The device comprises micron-scale threads that are implanted into specific regions of the brain responsible for movement control. Each thread has several electrodes that connect to an implant. [27]



Neuralink is funded by 15 investors. [25] **Vika Ventures** and **Raison** are the most recent investors. [26] **Neuralink has a post-money valuation in the range of $500 million to $1 billion** as of Jun 30, 2021, according to PrivCo. [26]

26. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/
27. Studio, P. (n.d.). Neuralink. Retrieved October 21, 2022, from https://neuralink.com/

Synchron

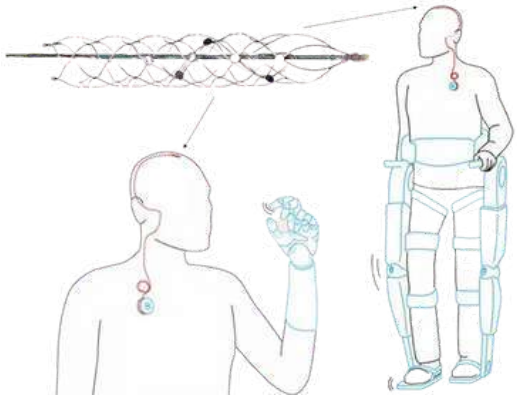
Synchron, an endovascular brain interface company, is a leader in implantable neural interface technology. The clinical-stage company is developing a neuroprosthesis for the treatment of paralysis and the first endovascular implantable neuromodulation therapy.

In July 2022, Synchron made an announcement about the **successful implantation of a BCI device in a human in the United States.** This milestone represents a significant advancement in scalable BCI technology and is the **first instance of an endovascular BCI approach being used in the U.S.** This approach is considered implantable, but it does not require open-brain surgery. [30]

The BCI implantation procedure took place at Mount Sinai West in New York, led by clinical investigator Shahram Majidi, MD, who serves as an assistant professor of neurosurgery, neurology, and radiology at the Icahn School of Medicine at Mount Sinai. The procedure was conducted using an endovascular approach in the angiography suite. The Department of Rehabilitation and Human Performance at Mount Sinai provided coordination for the procedure. [30]

The procedure **marks the first U.S. patient implant in Synchron's COMMAND trial,** which is being conducted under the first **investigational device exemption (IDE) awarded by the FDA** to a company assessing a permanently implanted BCI. The U.S.-based trial is being conducted with support from the NIH Neural Interfaces Program. [30]

Synchron has raised a total of $130M in funding over 5 rounds. Their latest funding was raised on Dec 15, 2022, from a Series C round. [28] In addition, Synchron is funded by 23 investors. **Subversive Capital**, **Max Hodak and Khosla Ventures** are the most recent investors. [28] **Synchron has a post-money valuation in the range of $10M to $50M** as of Apr 4, 2017, according to PrivCo. [28]



About the Stentrode™

The Stentrode is a medical device that is implanted in the motor cortex of the brain through an endovascular procedure via the jugular vein. Its function is to detect motor intent and transmit it wirelessly using a proprietary digital language. This technology enables severely paralyzed patients to control personal devices hands-free with point-and-click functionality. [29]

The trial assesses the impact of everyday tasks such as texting, emailing, online shopping and accessing telehealth services, and the ability to live independently. It is designed to be user-friendly and dependable for patients to use autonomously. [29]

The FDA granted Breakthrough Device designation to Synchron in August 2020. [30] Future applications include the potential to diagnose and treat conditions of the nervous system, including Parkinson's disease, epilepsy, depression, and hypertension. Synchron is headquartered in New York City, with R&D facilities in Melbourne, Australia. [30]

28. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/
29. Unlocking the natural highways of the brain. Synchron. (n.d.). Retrieved October 21, 2022, from https://synchron.com/
30. Synchron announces first human U.S. Brain-Computer interface implant. Business Wire. (2022, July 19). Retrieved October 21, 2022, from https://www.businesswire.com/news/home/20220719005248/en/Synchron-Announces-First-Human-U.S.-Brain-Computer-Interface-Implant

BlackRock Neurotech

Blackrock Neurotech is a company that offers advanced tools and expertise in neurotechnology to create implantable clinical solutions. Their precision electrode technology is frequently utilized in BCI developments. Certain individuals have reported improvements in their physical abilities as a result of using this technology.

Neuro Devices:
BlackRock Neurotech offers support to patients, clinical decision-makers, and medical device companies by providing a range of tools and products that aid in the diagnosis and treatment of neurological disorders. Their platform of technologies includes various neural interfaces (electrodes), biocompatible materials, and implantable electronics. [31]

Brain-Computer Interfaces:
BlackRock Neurotech has developed various implantable BCI systems. One of their FDA-cleared BCI systems is the **NeuroPort Array**, which is a miniaturized, wired system that has been shown to be effective through over 7 years of chronic implantation in humans and nearly 10 years in non-human primates. [31]


the NeuroPort Array

Blackrock Neurotech has raised a total of **$10M** in funding over 2 rounds. [32] Their latest funding was raised on Nov 1, 2021 from a Convertible Note round. Blackrock Neurotech is funded by 8 investors. [32] **What If Ventures** and **WPSS.bio** are the most recent investors. [32]

Blackrock Neurotech has invested in **Phantom Neuro** on Mar 25, 2022. [32] This seed round investment was valued at **$3.3M.** Blackrock Neurotech has also acquired **Mind-X**, **on Apr 20, 2022.** [32]

31. Blackrock Neurotech. (2022, September 26). Retrieved October 21, 2022, from https://blackrockneurotech.com/
32. Discover innovative companies and the people behind them. Crunchbase. (n.d.). Retrieved October 21, 2022, from http://www.crunchbase.com/

Paradromics

Paradromics is a privately-held company founded in 2015 by Matt Angle, a former physicist, with the aim of developing high-bandwidth brain-machine interfaces. [33] The company's technology is based on neural dust, a wireless, implantable platform that can record and stimulate neurons in the brain. [34]

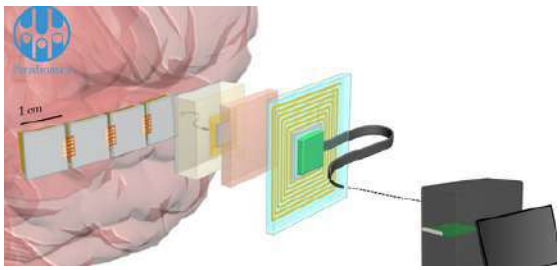
Paradromics has developed a number of products based on this technology, including the **Neural Interface Processor (NIP)** and the **Neural Dust Sensor (NDS)**. [34] The NIP is a custom-designed chip that can process high-bandwidth neural data in real time, while the NDS is a wireless, implantable device that can record and stimulate neurons in the brain. [34]

Paradromics' technology has potential applications in various fields, including the treatment of neurological disorders such as Parkinson's disease, epilepsy, and depression, as well as in neuroprosthetics and virtual reality. [35] One advantage of the company's technology is its high bandwidth, allowing for the recording and stimulation of a large number of neurons simultaneously. [35] This feature may be particularly beneficial in the treatment of neurological disorders, where precise targeting of specific neurons is important.

Paradromics has established partnerships with several leading institutions, such as the University of California, Los Angeles (UCLA), and the University of Texas at Austin. However, it is important to note that like any technology, there may be challenges and risks associated with its development, regulatory approval, and commercialization.

In 2016, the company raised **$7 million in seed** funding from **Founders Fund, Lux Capital**, and other investors. [36] In 2017, Paradromics was awarded an **$18.1 million contract from the Defense Advanced Research Projects Agency (DARPA)** to develop neural interface technology for treating brain disorders in humans. [37]

In addition, it **received grants from the National Institutes of Health (NIH) and the National Science Foundation (NSF)**. [37] Additionally, Paradromics has received support from UCLA and the University of Texas through research collaborations and funding opportunities. The company currently has a total of **$58.3 million** in **funding**.



33. Aggarwal, N. (2019, November 1). Paradromics: Neural dust and high bandwidth brain-machine interfaces. Medgadget. https://www.medgadget.com/2019/11/paradromics-neural-dust-and-high-bandwidth-brain-machine-interfaces.html
34. Paradromics. (n.d.). About. Retrieved March 3, 2023, from https://www.paradromics.com/about
35. Allied Market Research. (2021). Brain-computer interface market by type (invasive, non-invasive, and partially invasive), application (healthcare, gaming, and communication & control, and others), and end user (medical, defense, and others): Global opportunity analysis and industry forecast, 2021-2028. https://www.alliedmarketresearch.com/brain-computer-interface-market
36. Business Wire. (2016, June 29). Paradromics raises $7 million for neural interface development. https://www.businesswire.com/news/home/20160629005174/en/Paradromics-Raises-7-Million-for-Neural-Interface-Development
37. Business Wire. (2017, October 31). Paradromics awarded $18.1 million DARPA contract to develop neural interface technology for treating brain disorders in humans. https://www.businesswire.com/news/home/20171031005325/en/Paradromics-Awarded-18.1-Million-DARPA-Contract-to-Develop-Neural-Interface-Technology-for-Treating-Brain-Disorders-in-Humans

GlaxoSmithKline (GSK)

GSK, or GlaxoSmithKline, is a multinational pharmaceutical and biotechnology company headquartered in Britain. It is among the largest research-based pharmaceutical companies globally and is involved in the discovery, development, manufacturing, and marketing of human health products.

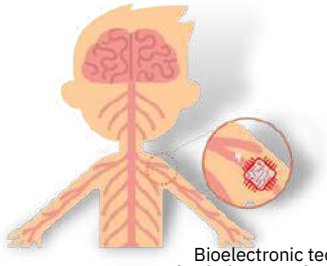
According to Crunchbase, GSK has raised a total of **$25.5M in funding** over 2 rounds. Their latest funding was raised on Mar 2, 2021, from a Grant round. [38]

In 2013, GSK declared its intention to explore the development of new treatments for disease by controlling neuronal activity in visceral organ systems, an area where the company perceives potential for translating innovative neurotechnology into precision treatments for chronic diseases, including but not limited to asthma, hypertension, and arthritis. [39]

Since then, the GSK Bioelectronic Medicines program has furthered work in the research community in this area through multiple efforts.

GSK investments: the BRAIN initiative and Bioelectronic Technology

GSK has offered funding of up to $5 million to support the development of the BRAIN initiative, which seeks to transform our knowledge of the human brain. Furthermore, GSK has established a $50 million fund to investigate medications and technologies that utilize electrical signals in a person's nerves to aid in the treatment of diseases. [40]



Bioelectronic technology

In January 2022, GSK administered treatment to the initial patient using a bioelectronic implant designed to alter nerve signals to organs located in the body's core. This treatment is part of a collaborative effort with Verily, a subsidiary of Google, to address chronic diseases. Galvani Bioelectronics was established by GSK and Verily in 2016 to develop implants capable of accurately targeting nerves in specific organs and remaining inside a patient's body for the remainder of their life. [39]

38. GlaxoSmithKline - Crunchbase Company Profile & Funding. Crunchbase. (n.d.). Retrieved March 2, 2023, from https://www.crunchbase.com/organization/glaxosmithkline
39. Brain fact sheet: Over $300 million in support of ... - brain initiative. (n.d.). Retrieved October 21, 2022, from https://braininitiative.nih.gov/sites/default/files/pdfs/brain_factsheet_09302014_508c.pdf
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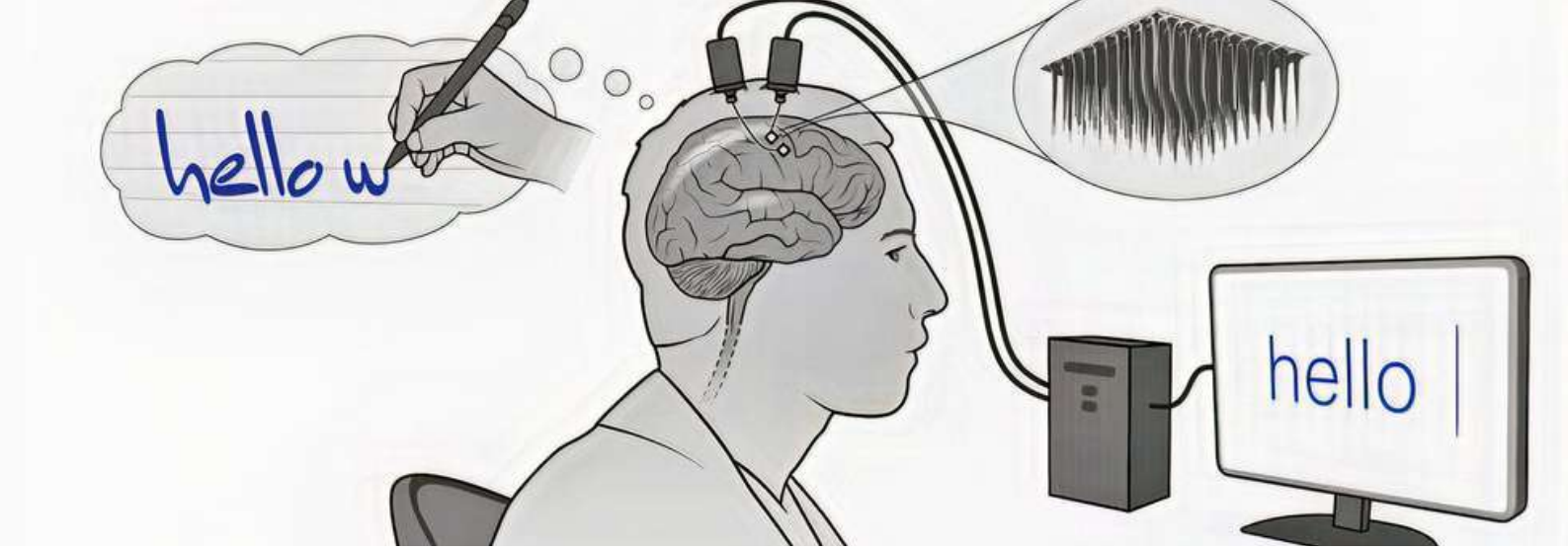

BrainGate

BrainGate is a collaborative research team of leading neurologists, neuroscientists, engineers, computer scientists, neurosurgeons, mathematicians, and other researchers - all focused on developing brain-computer interface (BCI) technologies to restore the communication, mobility, and independence of people with neurologic disease, injury, or limb loss.

BrainGate has been involved in extensive research and development, and is at the forefront of efforts to provide severely motor-impaired individuals with the ability to interact and function solely through their thoughts.

By using an array of micro-electrodes implanted into the brain, BrainGate's research team has shown that the neural signals associated with the intent to move a limb can be “decoded” by a computer in real-time and used to operate external devices. This investigational system, also called BrainGate, has allowed people with spinal cord injury, brainstem stroke, and ALS to control a computer cursor simply by thinking about the movement of their own paralyzed hand and arm. [41]

BrainGate has multiple research teams at Brown University, Emory University, Massachusetts General Hospital, Stanford University, University of California, Davis, and VA Providence Healthcare System. [41]

Funding for BrainGate research is now entirely from federal and philanthropic sources. The current annual budget is unknown, but it is estimated to be over $500 million. [41]

41. BrainGate. (2022, February 9). Retrieved October 27, 2022, from https://www.braingate.org/

Johnson & Johnson

Johnson & Johnson is a company involved in researching and developing, manufacturing, and selling various products in the healthcare sector. The company functions through three business segments: Consumer, Pharmaceutical and Medical Devices, and Diagnostics.

Johnson & Johnson's medical devices portfolio encompasses a range of innovative business segments that support professionals with tools for treating heart rhythm disorders and neurovascular care. The company also offers a variety of biomaterial products that supplement the use of traditional metal implants in surgical procedures for trauma, spine, and craniomaxillofacial applications. [42]

The net worth of Johnson & Johnson is approximately 90 billion dollars. [43]

Johnson & Johnson's medical devices and diagnostics segment earned about 9.8 billion U.S. dollars through its surgery franchise, specifically in 2021. [43]

Cerenovus: Neurovascular and Stroke

Cerenovus is a part of the Johnson & Johnson Medical Devices Companies and is dedicated to providing neurovascular care with the aim of improving stroke outcomes. Cerenovus offers a wide range of devices that are used in the endovascular treatment of hemorrhagic and ischemic stroke. [42]

Johnson & Johnson has been steadily acquiring smaller medical device companies in order to strengthen Cerenovus' product portfolio. In late 2016, Johnson & Johnson subsidiary Codman Neuro acquired **Pulsar Vascular Inc.**, a company focused on treating wide-neck bifurcation aneurysms. [44]

42. Medtech. Content Lab U.S. (n.d.). Retrieved October 27, 2022, from https://www.jnj.com/healthcare-products/medtech
43. Stewart, C. (2022, February 21). J&J Medical Devices and diagnostics sales by franchise 2018-2021. Statista. Retrieved October 27, 2022, from https://www.statista.com/statistics/266406/revenue-of-johnson-und-johnsons-medical-devices-and-diagnostics-segment/
44. Hand, S. (2019, May 8). Johnson & Johnson launches neurovascular business with focus on developing stroke therapies. Xtalks. Retrieved October 27, 2022, from https://xtalks.com/johnson-and-johnson-neurovascular-business-914/

Challenges and Opportunities

Opportunities

Scientific

Brain-computer interfaces enable scientists to both record and manipulate brain activity. This can let researchers get at the deep mystery of how neural circuits function and understand how the brain works.

Medical

Brain-computer interfaces could enable neurologists and psychiatrists to diagnose and better understand mental and neurological diseases and develop novel therapies.

As seen in our analysis, companies such as Neuralink, BlackRock Neurotech, and BrainGate research teams are developing BCIs that could allow people with paralysis to spell words on a computer screen or regain control of their limbs. In addition, researchers at Syncheron and Meta are developing BCI-controlled robotic limbs that can provide users with a sense of touch.

Economic

Neurotechnology, particularly non-implantable brain-computer interfaces, could provide a new platform to enable the connection between humans and the net instead of current devices.
Innovative non-implantable BCI technologies such as Meta's EMG wristband, Emotiv wearables, and Kernel Flow, among others, generate a new field of economic innovation for the tech industry.

Challenges

Brain-computer interfaces have the potential to foundationally alter society. As seen in our analysis, it is already nearly possible to decode thought from neural activity or enhance cognitive ability by linking the brain directly to digital networks. Such innovations could challenge the very notion of what it means to be human.

Therefore, although brain-computer interfaces present critical opportunities for scientific and medical breakthroughs and will open a vast new field for economic development, they also present unprecedented human rights and ethical implications.

Brain-computer interfaces have tremendous potential to improve the human condition and advance our species, but precisely because they can be so transformative, they also raise fundamental human rights challenges and ethical concerns that were never envisioned.

Consequently, existing regulations cannot offer the robust and comprehensive protection that a world of people using brain-computer interfaces requires.

About the Neurorights Foundation

The Neurorights Foundation is a non-profit promoting innovation, protecting human rights, and ensuring the ethical development of neurotechnology. We engage the United Nations, regional organizations, national governments, companies, entrepreneurs, investors, scientists, and the public at large to raise awareness about the human rights and ethical implications of neurotechnology.

The NeuroRights Foundation work at four levels:

International

Neurotechnology raises fundamental human rights challenges that were never envisioned by today's international human rights treaties. Instead, today's era calls for a novel protection framework.

The Foundation's main goal is to protect the human rights of all people from the potential misuse or abuse of neurotechnology.

We are working to incorporate five specific **Neuro-Rights** (see below) that have been identified as especially critical into international human rights law, national legal and regulatory frameworks, and ethical guidelines.

National

Governments need to develop and adopt a new legal and regulatory framework to govern the development and use of neurotechnology that will provide protection against the misuse of neurotechnology.

Industry

It is essential to develop a new ethical code in collaboration with companies, entrepreneurs, scientists, and investors that can set the standard for self-governance and accountability.

General Public

It is important that wide efforts be undertaken to highlight the exciting current and forthcoming developments in neurotechnology and explain how such technology might be misused or abused.

The Five Neuro-Rights

Mental Privacy

Any NeuroData obtained from measuring neural activity should be kept private. If stored, there should be a right to have it deleted at the subject's request.

The sale, commercial transfer, and use of neural data should be strictly regulated.

Personal Identity

Boundaries must be developed to prohibit technology from disrupting the sense of self.

When neurotechnology connects individuals with digital networks, it could blur the line between a person's consciousness and external technological inputs.

Free Will

Individuals should have ultimate control over their own decision making, without unknown manipulation from external neurotechnologies.

Fair Access to Mental Augmentation

There should be established guidelines at both international and national levels regulating the use of mental enhancement neurotechnologies.

These guidelines should be based on the principle of justice and guarantee equality of access.

Protection from Bias

Countermeasures to combat bias should be the norm for algorithms in neurotechnology.

Algorithm design should include input from user groups to foundationally address bias.

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