THE power of human thought is incredible – our imagination even more potent than our intelligence. Our brain, equipped with 80-100 billion neurons and 10^15 synapses, is practically a thinking, feeling, biological computer. While our brains and bodies have miraculous capabilities to achieve seemingly unthinkable feats, they too are susceptible to various diseases, disorders and injuries that significantly hamper their functioning.

What if we could use technology to recover from diseases, making up for amputated or injured body parts and even enhancing their normal cognitive and physical abilities?

This is where sci-fi fantasy of a BMI (Brain-Machine Interface) or BCI (Brain-Computer Interface), now a subject of serious scientific research and inquiry, comes into play. BCI essentially provides a communication path between the human brain and computers, relaying information bi-directionally between the two. These devices have immense potential, particularly in Medicine, Military, Manufacturing, Gaming and Communications.

However, if BCI technology is misused or used carelessly, it could lead to disastrous consequences. Thus, there is a pressing need to understand the device, contemplate and analyse the problems it poses, and come up with solutions to manage these.

What is BCI?

Popular portrayal of Brain-Computer Interfaces gives rise to a very specific perception of a device like a helmet worn over the head, which records brain activity and sends signals to control an external device. While BCIs do work similarly, they can be of various types.

Mental activity causes changes in electrophysiological signals (voltage fluctuations resulting from ionic current within a neuron) in the brain, for example, the ‘EEG’. In fact, BCI was born with the development of EEG (Electroencephalography) by Hans Berger. Berger invented a means of recording and analysing electrical activity of the human brain in 1924. By analyzing these signals, Berger was able to identify oscillatory activity in the brain, such as the Berger’s wave (8–12 Hz) and analyse the relation of alternations in the EEG wave diagrams with brain diseases.

Present day BCI systems work by acquiring electrophysiological changes, transforming them into an electrical signal, and sending this command to a computer or machine to carry out the desired action. Depending on the positioning of the sensors used to record brain signals, BCI systems can be categorised as:

**Non-invasive:** When sensors are placed on the scalp, measuring either the electrical potentials produced by the brain (EEG) or the magnetic fields with a method known as Magnetoencephalography (MEG). An example of a device that uses EEG is the ‘Emotive Insight Headset’.

Commonly known terms such as MRI (Magnetic Resonance Imaging) and fMRI (functional Magnetic Resonance Imaging) are forms of the latter kind of BCI since both of these use magnetic fields to capture brain activity.

**Semi-invasive:** When electrodes are placed within the skull – on the exposed surface of the brain – instead of on the scalp like in EEG, it is called electrocorticography (ECoG).

**Invasive:** When micro-electrode arrays are buried within the brain itself through complicated neurosurgery. They are implanted directly into the cortex. These tend to cause build-up of scar-tissue.

Diagrammatic representation of Invasive BCI, where the electrode is inserted directly into the grey matter

Applications

Astonishingly, over 50,000 BCIs are sold per year in the form of cochlear implants! A small computer with a microphone, a cochlear implant attaches to the CNS to restore the hearing of deaf people.

BCI devices are of utmost importance to those who are paralysed or suffer from diseases like ALS (Amyotrophic Lateral Sclerosis). The patients’ bodies often lose control over their full motor function and their ability to speak. A Speech-Generating Device aided late theoretical physicist Stephen Hawking to allow him to ‘speak’. Now, with the help of a BCI, a person with paralysis would simply be able to translate thoughts into spoken words through the machine, making the process much simpler and faster for the patient to learn and use.
Scientists have developed a brain-computer interface that reads the brain’s blood oxygen levels in people who have even lost the capability to move their eyes. The BCI technique used technologies called near-infrared spectroscopy (fNIRS) and EEG to measure blood oxygenation and electrical activity in the brain, which were then analysed to identify trends/patterns and calculate whether the individual responded to the question asked with a ‘yes’ or a ‘no’.

While this form of communication may seem fairly rudimentary, it is a great advancement for people who’ve completely lost all movement. Paralysed and ALS patients can better communicate with their near and dear ones, surroundings and hopefully, add meaning to their lives.

Further, BCI is utilised in the emerging fields of neuro-engineering and neuro-prosthetics in order to, say, provide amputees with anthropomorphic prosthetic limbs that they can control like a real arm or leg. Cochlear implants and vision prostheses are also examples of neuro-prosthetics. A limb prosthesis can be remotely controlled by brain signals and allow users to experience the ‘feel’ of tactile information conveyed by the prosthetic limb. This is possible as BCI devices are ‘bi-directional’, meaning data travels both from the brain to the arm and vice-versa. R&D for such technology is in the nascent stages.

Beyond the medical industry, BCI technology has many applications. For instance, it could be developed into a gaming console that allows you to put on a ‘gaming-visor’ and play the game through commands from your brain. Coupled with a virtual reality lens, it would create a completely immersive gaming environment where a player would feel as though they’re inside the fictional world and move through it as naturally as they do in real life.

Another example of BCI’s use in the fields of art and medicine is ‘brain painting’, allowing injured artists to express themselves creatively using their thoughts rather than their hands. Such applications in other fields of entertainment such as films, music, amusement parks, etc. open up a whole new world of possibilities that could transform the way we explore, interact socially, express ourselves, and consume popular culture.

It could also be put to more serious use. BCIs can help monitor the mental states of people. They can be useful in the treatment of mental health disorders, in analysing and increasing the productivity of employees by measuring attention and focus, in curing drug addictions, and more.

Problems
Not all is sunshine and roses. Although a BCI could have great benefits, it also has negative ethical, legal, and social implications.

Moral problems: BCI could just be the second coming of plastic surgery. Similar to how we perceive surgery to be helping those in need, we tend to focus on the medical applications of BCI that can help patients lead a better life. However, it could be used by humans to enhance their existing human capabilities – in place of prosthetic limbs someone might like to have a mentally-controlled exoskeleton, create an Iron Man-style suit, or improve their hearing or vision to superhuman capacity. This can be exploited in the military to create unreliable super-soldiers who could press the trigger through their thought.

A BCI could offer an unfair advantage in careers such as athletics. It could let people gain unnatural superhuman
strength to circumvent law and order. This could not have just legal implications, but economic inequality and moral dilemmas as well. BCI will divide the world into haves and have-nots, helping create a superhuman race of people akin to the X-Men. But who should have access to this expensive tech? Should it be allowed to concentrate in the hands of the rich? What responsibilities should accompany its ownership?

**Safety and privacy:** The unsecured brain data recorded by BCI could provide hackers unauthorised access to people’s medical records, which would pose a great threat in the wrong hands. In a research study “On the Feasibility of Side-Channel Attacks with Brain-Computer Interfaces” (https://www.usenix.org/conference/usenixsecurity12/technical-sessions/presentation/martinovic), researchers found a way to extract sensitive information from a person’s brain, such as PIN numbers and bank information!

In addition, advertisers who are right now exploiting personal data on social media such as Facebook could use the information by a BCI to show advertisements that are tailored to patients’ thoughts.

BCI, in the future, could be used to help comatose patients communicate in very simple ways and make decisions about voluntary euthanasia. Institutions like hospitals would like access to this data, but the question arises – who owns the information collected by the BCI? The individual, private institutions, or the government?

**Health:** Every new technology arrives hand-in-hand with health complications; BCI is no exception. Invasive BCIs, in particular, can cause side effects like infection and haemorrhages as they need to be surgically implanted.

We must also remember that our brain is part of a larger biological framework and does not work in isolation. While we may focus on the harmful effects of the device on the brain, it could be leading to other bodily problems we may remain unaware of until they manifest themselves years later.

**Philosophical:** At what point in time does an artificially enhanced or repaired human transcend being a *Homo sapien*? If the technology develops to allow brain-to-brain communication, where does one person’s thought end and another’s begin?

Brain-computer interfaces are a fascinating, emerging field of science with wide-ranging applications. However, the variety of concerns this technology raises need to be managed before it is advanced enough to be in widespread use. This will require several minds to work together – policymakers, researchers, doctors, engineers, industrial manufacturers, and users – to reach constructive solutions.

The society needs to understand the working of a BCI in order to utilise its full potential to help people without infringing upon their rights, safety, freedom and health!

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