**The current uses of Brain Computer Interfaces in Medicine and the ethics surrounding its use**

According to Shih et al, “A brain-computer interface (BCI) is a computer-based system that acquires brain signals, analyzes them, and translates them into commands that are relayed to an output device to carry out a desired action” [1]. The signals are sent straight to an output device, bypassing the peripheral nerves and muscles which are the normal output pathway of the brain [1]. The main purpose of a BCI is to correctly encode brain signals and create a physical output that aligns with the user’s intended actions [1]. Initially, BCI requires practice by both the machine and its user as it is not a natural occurrence for either participant [1]. The user must learn to generate the correct brain signals for encoding, while the machine must learn to correctly decode these signals [1].

To function as intended, a BCI consists of four sequential components. They are as follows: 1) signal acquisition, 2) feature extraction, 3) feature translations and 4) device output [1]. Signal acquisition includes the measuring, filtering, and amplification of brain signals which are digitized and sent to a computer [1]. Feature extraction refers to the analyzing of the digital signals to determine the user’s intent. In feature translation, the chosen signals are passed to the algorithm which converts the signals into commands for the output device [1] The device output then operates based on the commands generated during the feature translation phase. This step provides feedback to the user. It highlights if the device created the user’s indented movements or if something was incorrectly encoded or decoded during the process. It is important to note that all components of a BCI are monitored and controlled by an operating protocol which ensures user flexibility, uniqueness, greater levels of efficiency and detailed definition of signal processing and device commands [1].

The use of brain computer interfaces in medicine has risen drastically over the past decades. BCI can have a variety of uses during the prevention, detection, diagnosis, rehabilitation, and restoration phases of healthcare [2]. When most people think of BCI in medicine, it is normally

associated with correcting serious traumatic brain injuries. This is supported in the article by Shih et al, which states that “the main goal of BCI is to replace or restore useful function to people disabled by neuromuscular disorders such as amyotrophic lateral sclerosis, cerebral palsy, stroke, or spinal cord injury”. However, BCI in medicine can be used for other illnesses such as addictions (smoking and alcoholism) and even motion sickness issues [2]. There has been much research regarding the use of BCI to detect the harmful effects of smoking and alcohol use on the brain and how these drugs manipulate our brainwaves [2]. Although these effects may be common knowledge to most, these studies are able to go into more depth by investigating the parts of the brain that respond the most to alcohol or smoking and the possible loss of brain function it may cause in the future [2]. Using BCI to study motion sickness has also been key for researchers as there tends to be dire consequences for those who are affected unsuspectedly while driving. According to Sarah et al [2], “motion sickness occurs as a result of sending conflicted sensory information generated from the body, inner ear and eye to the brain”. It can cause serious traffic accidents as it causes a decline in a person’s ability to maintain self-control [2]. BCI can be useful in such an instance as it may be able to predict the unset of motion sickness for an unsuspecting driver and reduce the chances of an accident occurring [2]. This is done via a process called consciousness level monitoring [2].

BCI can also play an important role in the detection and diagnosis of diseases [2]. According to Sarah et al, “the mental state monitoring function of BCI systems has also contributed to forecasting and detecting health issues such as abnormal brain structure (e.g., tumor), seizure disorders (e.g., epilepsy), sleep disorders (e.g., narcolepsy) and brain swelling (e.g., encephalitis). Without the ability to constantly monitor, read and interpret brain signals most of these brain issues would go undiagnosed, and therefore remain untreatable. Researchers have also been interested in using electroencephalogram (EEG-based brain tumor detection as a cheaper, secondary alternative to MRI and CT-SCANs [2]. An alternative, more cost-effective way of detecting brain tumors or other diseases would be revolutionary for the medical industry as it would increase the opportunity for more people to have access to more affordable medical aid.

However, despite all the good, there are certain risks associated with BCI. Any device that requires surgical interventions and must be implanted under the skin or skull within proximity to the brain, carries the risks of complications due to infections and/or acute trauma to surrounding brain tissue [3]. A major concern is raised regarding long term implants as they are more likely to develop glial scarring, which can surround the implant and prevent the BCI from operating as expected [3].

There is also a concern about the mental impacts of BCI. Many researchers wonder if after a BCI is removed, does the patient go “back to normal” or is their brain chemistry forever altered from use of either invasive or non-invasive BCI devices [3]. For example, some people have reported concerning changes within loved ones after deep-brain stimulation (DBS) for diseases such as Parkinson’s disease. There were changes such as developing impulse-control issues such as hypersexuality or on the other end of the spectrum where emotional awareness was lessened, and people became extremely apathetic [4]. Because of these changes, some users begin to wonder how much of themselves is really them, and even claim to feel “artificial” [4]. Although their physical illnesses have been sedated, these patients often face a new battle - a battle for their old selves and an accurate perception of their current selves. It should also be noted that some patients are not even aware of these changes until the BCI is turned off, despite being told by family and/or friends. This then raises another issue - is a person who is undergoing BCI able to make informed decisions and give consent when necessary if they are oblivious to changes in their personality? If this patient sees no issue and continues to give consent, can a family member or doctor step in and overrule them? However, if the latter is possible then the argument can be made that BCI interferes with people’s ability to make informed decisions for themselves and suggests that if a person behaves a certain way when their brain chemistry is being altered, then this is not a true reflection of the person or the decisions he/she would have made prior to BCI.

Some researchers are also worried about the general merging of humans and technology. With the direct connection to the brain, a potential door is opened for new violations of user privacy,

as BCI may be able to extract information from the brain unbeknownst to the user [3]. There is also the potential for BCI devices to reveal private information such as mental states and attitudes towards other people [3]. The user basically becomes an open book, as their thoughts and feelings are no longer their own. With an always active and accessible path from the brain directly to the outside world, BCI users may have to be more conscious of their thoughts compared to the average person. Researchers also note that a BCI device can be hacked due to its wireless nature [3]. Like any technological device, an attacker can find some way to compromise it and steal the desired information. The information being stolen would be even more personal than the information on personal devices such as phones since the attacker now has a direct connection to the person’s brain. In an attempt to prepare for such hypothetical scenarios, researchers have started dabbling into “neurosecurity” - essentially the security of the brain [3]. It is also important to note that harmful exploits can also affect the hardware of the BCI device and cause it to malfunction [3]. This puts the user at an extreme risk for brain injuries.

Patients have also raised concerns about not being viewed as fully human if they use brain computer interfaces. Researchers also have these concerns as seen in an article by Demetriades et al. where they argue that being more robotic makes ones less human, and that BCI could generate the “risk of losing what makes us human”. Although this is a fair point, it also makes way for the contrary, should we continue to suffer in our humanity/mortality when we have the technology and medical wisdom to provide a better life for mankind? Due to technology, some researchers believe we may be able to surpass human limitations and create a better standard of life for ourselves [3]. This evolved species would be dubbed “Homo sapiens technologicus” [3]. However, most BCI users reject this idea and refuse to see themselves as anything but human [3]. This could be mainly due to the fact that being seen as different from the societal norm can be alienating.

As BCIs becomes more widely available, there is no doubt that more issues/concerns will be brought to the forefront, with ethics, cost and ease of accessibility being some of the most

prominent. Also, as time passes and technology continues to improve, where do we draw the line when it comes to maintaining our humanity but still making the best use of the technology and research we have at our disposal? Depending on what the future holds, there is the potential for BCI use to look different for many of those involved.

**References**

**1)**Shih JJ, Krusienski DJ, Wolpaw JR. Brain-computer interfaces in medicine. Mayo Clin Proc. 2012 Mar;87(3):268-79. doi: 10.1016/j.mayocp.2011.12.008. Epub 2012 Feb 10. PMID: 22325364; PMCID: PMC3497935.

**2)** Sarah N. Abdulkader, Ayman Atia, Mostafa-Sami M. Mostafa,

Brain computer interfacing: Applications and challenges, Egyptian Informatics Journal,

Volume 16, Issue 2,2015, Pages 213-230, ISSN 1110-8665,

https://doi.org/10.1016/j.eij.2015.06.002.

(<https://www.sciencedirect.com/science/article/pii/S1110866515000237>)

**3)** Burwell, S., Sample, M. & Racine, E. Ethical aspects of brain computer interfaces: a scoping review. BMC Med Ethics 18, 60 (2017). https://doi.org/10.1186/s12910-017-0220-y

<https://bmcmedethics.biomedcentral.com/articles/10.1186/s12910-017-0220-y>

**4)** L. Drew, “The ethics of brain–computer interfaces,” Nature News, 24-Jul-2019. [Online]. Available: https://www.nature.com/articles/d41586-019-02214-2. [Accessed: Dec-2022].

<https://www.nature.com/articles/d41586-019-02214-2>