**The Clinical Possibility of Brain-Machine Interfaces (BMIs)**

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**Abstract:**

Artificial Intelligence (AI) continues to rise in popularity across the world, and its use has revolutionized multiple spheres of life in society. Recently, Elon Musk has been trying to combine this technology within the human mind itself through his company Neuralink. By implementing a brain-machine interface (BMI), new methods of treatment and prevention are possible, potentially providing solutions for currently uncurable diseases, such as Alzheimer’s or Dementia.

This future advancement, however, carries numerous implications, not just medically but both financially and socially. While providing the chance to change the understanding of the brain itself and certain neurological diseases, BMIs also may bring about numerous risks towards a patient. Considering all the potential effects of BMIs, the overall clinical possibility of this groundbreaking technology must be considered.

**Introduction:**

With the ongoing development and investment of BMIs by some companies, the future remains unclear and highly variable. Therefore, this article identifies key details that helps to answer an obvious question. What is the clinical possibility for the technology of brain-machine interfaces (BMIs) based on numerous questions of its viability? As there are numerous documented advantages with BMIs, the clinical possibility for this technology is very bright, opening the gates for medical breakthroughs. However, the cost, daily life, and implementation within the patient of this technology needs to be further researched; regardless, these concerns still can be overcome as the technology continues to be developed. Furthermore, public perception must be analyzed to understand various issues that may need to be addressed as development continues closer to clinical trials.

The development of BMIs has rapidly increased lately; however, its core aim is not a new one of aiding patients’ neurological issues with the use of technology within the brain [1, 2]. With a BMI, the connection between the nervous system and codable devices allows for the advancement of rehabilitation of neurological injury [3]. A variety of technologies have been developed to aid with certain neurological issues by electrically stimulating nerve cells since the 1950s [1]. Furthermore, in the 1970s, scientific research was done using technology to record neurons of living monkeys that allowed researchers to explore the neurophysiology of the brain cortex of a monkey [4]. Recently, a design of a BMI has been released that confers a more convenient, increased mobility machine that will be further improved by future implementations [5].

Currently, BMIs have grown in potential due to the revolutionary research done by certain companies like Neuralink and BrainGate [6]. During the launch of Neuralink, Elon Musk described the objective of the company to further gain knowledge of the brain and enhance, thereby “*creat*[ing] *a well aligned future*” [6]. Recently, Neuralink was able to design a BMI with improved specifications that provides a “*research platform*” in rodents and a “*prototype for future human clinical implants*” [7]. Although a clear indication of a breakthrough in development by Neuralink does not exist, a path of direction has been established with an increasing range of potential applications [8].

As the development of BMIs has dramatically increased in the past decade, the future is now more important than ever. Merging Artificial Intelligence with the brain is not a small feat, and if it is done incorrectly, it may have irreparable consequences upon society. For that reason, my goal to evaluate the known information about the current state of BMIs allows me to analyze future areas of concern and identify needs for additional research. With a review of potential dangers and applications of this technology, a determination of its clinical possibility can be made, providing a path for researchers to alter their methods to provide for a better future.

**Methods:**

For my research, I analyzed numerous articles to determine the clinical future of BMIs. Searching for these articles, I utilized databases like PubMed with the following keywords: “Brain-Machine Interfaces,” “Clinical Possibility of Brain-Machine Interfaces,” “Neuralink,” and “BMIs.” Within each paper, I focused on sections that discussed the implications of BMIs in various aspects of society. Particularly, I searched for the range of effects this technology could have in medicine, including new areas of treatment and cures it could present for certain diseases. However, I noted various concerns, including long-term care, surgical implementation, and public perception. I also included other theoretical possibilities of BMIs, such as if the technology malfunctions in some way or if it could be exposed to outside tampering like hacking.

Additionally, I highlighted certain parts of each article that contained information about current or past research efforts. These details provide context for the technology that helps to exam the current situation of BMIs within today’s world, thereby preparing for an understanding of the future situation. After collecting these materials, I can construct a comprehensive discussion of BMIs that organizes the potential positives and negatives of the technology. With this discussion, I am able to make a complete conclusion about the clinical possibility of BMIs and determine if future research in certain areas could help develop this technology further.

Nonetheless, various limitations endure within my research, including deficits of certain pieces of information. As development of new BMIs are in early developmental stages, current and past research mainly focuses on potential applications of the technology. However, relatively smaller aspects of the technology remain researched to a much smaller extent. For this reason, one objective of this paper is to identify current areas of further research. As time continues, more research and information will be published, thereby changing the circumstances that exist as this paper is written. Therefore, new areas of research and more potential hurdles may exist then for this evolving technology.

**Discussion:**

As BMIs are mainly developed in the past for patients who were totally paralyzed from certain strokes or degenerative diseases, current development of BMIs is widening its scope to disabled speech, missing limbs, and more efficient treatment for certain issues like seizures [1, 3]. In one trial, researchers measured the “*highest neural cursor control performances*” to date of two patients with amyotrophic lateral sclerosis (ALS) after the implementation of neural prostheses, a type of BMI, thereby revealing the true potential that BMIs can have [9]. Additionally, in another proposed integrated BMI system, some disabled patients would be able to send a “*neural transmission*” for their limbs to execute a timely task [5]. Although substantial challenges do exist to continue to help other patients’ diverse issues with BMIs, “*high-bandwidth neural interfaces*” would provide even more new treatments [7].

However, Elon Musk’s Company is trying not only to treat a wide range of medical issues with BMIs but also to enhance humans’ physical capabilities past their original state [1, 10]. Theoretically, BMIs have the possibility to allow a patient to use their senses using outside devices, thereby “*affecting cognitive, psychological, and emotional responses*” [8]. Furthermore, as Neuralink explores and understands the brain gradually more, futuristic exploits of “*fully immersive video games and simulations*” for the mind are also within Musk’s goals [1]. Through these new ideas, Elon Musk would be growing closer to creating a process of “*transferring the brain’s content to a machine and vice versa*,” a concept known as the “*Neural Lace*” [6]. Curiously, as we continue to gain more knowledge about the brain, new possibilities may be revealed that could not be imagined before, opening society to an even more variable future.

Nonetheless, all these potential changes are irrelevant without considering the public perception. As society continues to grow, the public must grow as well. However, the idea of a foreign technology implanting within our minds may trigger worrying fears and encroach upon certain values of freedom [1]. The prospect of abuse by overbearing governments, corporate entities is evident for economic, social, or political gain [1]. Furthermore, the sci-fi fantasy of simply “*uploading a computer virus into* [one’s] *brain*” altogether suggests the loss of any autonomy within society [1].

Additionally, the concept of this technology raises certain ethical concerns among many. Particularly, the idea of “meddling in a natural process” within the body can bring about irreversible repercussions upon patients [6]. Some address this concern by remarking that the body has always adapted to its surroundings, which currently comprises the evolving grasp of Artificial Intelligence [6]. Moreover, the risk of implanting an uncomfortable object within the brain with the limited resources of the healthcare system must also be weighed [6, 8].

Lastly, the surgical implementation of this technology presents a unique challenge for researchers and surgeons. Creating specific techniques for the implantation of various BMIs within different areas of the brain will require much time and research to ensure overall safety, being thoroughly evaluated [8]. Currently, some studies have demonstrated that “*implanting microelectrodes into the eloquent cortex…cause fine motor deficits*,” presenting a significant roadblock for researchers [8]. Furthermore, the issue of data collection for implant monitoring arises as many computer systems could struggle to contain, but the progress of “*high-performance computing systems and cloud-based comput*ing” seems promising, providing a potential solution to this issue [8, 9]. Additionally, the general security of patients’ data brings about numerous concerns as adjusted function and impairment of BMIs could lead to significant repercussions, called “*brainjacking*” [8].

**Conclusion:**

Considering all these aspects of brain-machine interfaces, the clinical future of the technology seems plausible with its revolutionary applications and growth. However, numerous questions still remain over various aspects of BMIs’ development.

First, the “*longer-term durability*” of BMIs needs to be documented within research to further assess its safety in the brain; moreover, approval processes and legal framework for this technology must begin to be discussed to provide an organized method of implant regulation [8]. Economically, questions arise to sources of funding for development of BMIs and certain conflicts of interests (COIs) [8]. Some gaps of research also exist as development of BMIs are in an early stage. An investigation of the customizability of BMIs based on the patients’ traits and cognitive abilities has not been detailed [10]. Additionally, further research needs to be conducted to detail potential freak accidents with BMIs as well as prevention and treatment measures.

All these deficits and issues with the research of BMIs must be resolved before a clinical possibility can be considered. Particularly, animal research will prove to be invaluable as it provides more information on numerous topics of BMIs, contributing to filling in these gaps [4]. As public perception remains unclear and blurred, complete transparency and exhaustive research must be produced to improve general knowledge. As more become aware of this technology’s capabilities and secure in its safety, public perception should then improve, but these steps are critical to this outcome. With these steps, the clinical translation of BMIs should become smoother and more efficient, providing a brighter future.

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