International Journal of Healthcare Sciences **ISSN 2348-5728 (Online)**
Vol. 11, Issue 1, pp: (70-78), Month: April 2023 - September 2023, Available at: **www.researchpublish.com**

Applications of Neuroscience and Virtual Reality for Neurorehabilitation

Marcus Kwon

DOI: https://doi.org/10.5281/zenodo.8054989

Published Date: 19-June-2023

Abstract: **This literary review provides a summary of the potential applications on the topic of full dive immersion and its applications in the field of neurorehabilitation. The review aims to explore the existing literature and research surrounding full dive immersion, examining its potential benefits, limitations, and future directions. Through comparing and cross-referencing existing methods of neurohabilitation as well as potential procedures of full dive immersion, this review hopes to examine the effectiveness of full dive immersion as a therapeutic tool for individuals with neurological disorders compared to traditional rehabilitation approaches. The findings of this literary review will contribute to a comprehensive understanding of the role and potential of full dive immersion in neurorehabilitation, guiding future research endeavors and informing clinical practices in the field. By synthesizing relevant studies and scholarly articles, this review seeks to shed light on the current state of knowledge and identify gaps in research which will contribute to a deeper understanding of the therapeutic potential of full dive immersion and its implications for neurorehabilitation.**

Keywords: **Neuromodulation, virtual reality, VR, Neurohabilitation, Full Dive Immersion.**

1. INTRODUCTION

Neurological disorders pose a significant challenge to individuals and society, affecting millions of people worldwide. These disorders can result in functional impairments, including motor, cognitive, and sensory deficits, necessitating effective rehabilitation strategies. Traditional rehabilitation approaches have been able to regain control in major areas such as motor control, but there remains a need for innovative interventions that can optimize recovery outcomes.

In recent years, the concept of full dive immersion became a more discussed topic. A concept derived from virtual reality (VR) technology, this new concept brought interest in the field of neurohabilitation. Full dive immersion offers a unique platform that creates an immersive and interactive virtual environment, engaging multiple senses to provide an enriched therapeutic experience. By simulating real-world scenarios, full dive immersion has the potential to augment traditional rehabilitation methods and address the limitations associated with conventional approaches.

This research paper aims to explore the therapeutic applications of full dive immersion in the context of neurorehabilitation through conducting a comprehensive literature review that analyzes the efficacy, advantages, and limitations of its utilization.

2. OVERVIEW OF CONTEMPORARY AND DEVELOPING TECHNOLOGY

2.1. Current Stage of Neuroscience and technological integration

Throughout recent advancements, the possibility of further integration of technology and biology is ever so present. Never before has society taken a huge step towards this development. One such scope is the neuroscience field. What started as the discovery of the transmission of electrical signals in the brain, led to developments such as the creation of electroencephalography (EEG), as well as fMRIs have allowed many applications of non-invasive recordings and measurements of brain activity. The ability to "graphically display patterns of brain activation," as well as other sources of brain mapping allows for "pre-surgery risk assessment, and observing post-surgery recovery, as well as the effects of pharmacological and behavioral therapies. Despite its major involvement within the medical field, it has also been applicable in the consumer world as well[1]. These readily available “pervasive neurotechnology applications" include brain-computer interfaces (BCIs), neurosensory-based response technology, cognitive training tools, electrical and magnetic brain stimulation, and virtual reality systems. With the use of fMRI, even neurological conditions such as depression and Alzheimer’s disease can now be medically diagnosed through medical personnel[2]. Another type of pervasive neurotechnology is the use of electrical brain stimulators. Transcranial magnetic stimulation (TMS), which is a way to stimulate specific regions of the brain for diagnostic and therapeutics through the use of magnets, has become optimized to fit into small devices which are marketed now as devices that are effective in treating migraines[3]. Including invasive techniques as well, As neuroimaging techniques and interpretations become better soon, humans will have a better understanding of the intentions of people. In one study, scientists were able to determine with 70% accuracy the tasks the subjects were intending to perform through their inferences using decoded brain activity[4]. Through multiple various brain studies across a variety of applications, it was determined that brain scans allow people to not only infer actions and opinions in an experimental environment but also allow the deduction of general human opinions, such as political views and hobby preferences. With new and better ways of interpreting human emotions and thoughts, many businesses have started to incorporate neuroscience into their marketing strategies, coining the term “neuromarketing”; companies such as Google, Disney, and Frito-Lay, utilize neuromarketing to better gauge consumer preference and impressions in their advertisements and products[2]. These methods help companies to create more efficient and optimized products as well as marketing techniques. New advancements in non-invasive brain control prompted major communication corporations such as Apple and Samsung into incorporating neurotechnology as add-ons to their product line. With this in mind, Yuan and his teammates have predicted that these neuro devices will eventually make the current technology of keyboard, touch screen, and mouse obsolete[5]. Some invasive methods are in use right now, most notably, a surgical technique known as deep brain stimulation (DBS) which implants a neurostimulator into the ventral intermediate nucleus of the thalamus. This method is used to help as a treatment for tremors, Parkinson’s disease, dystonia, and obsessive-compulsive disorder(OCD) [2].

Sensing-enabled epilepsy stimulation devices have allowed for scientists to study the circadian rhythm and the patterns of seizure risk. With medical technology’s scalability to the public, the current procedures for medical device approvals are simpler than pharmaceuticals. Since medical devices can be tested in smaller trials as opposed to the three-phase testing protocol for pharmaceuticals, it allows for better affordability and lower the costs of health services[6]. However, despite major improvements in detection accountability, the use of neurotechnology to treat mental disorders has been slow in comparison to its rising cases. While research has been put into the work of developing treatments for neurological disorders, the commitment to applying neurotechnology to treat neurological disorders has been slow, mainly due to the clinical and economic burden of the health administration system. As of now, medical devices are still treated in similar regards to pharmaceutical research and development (R&D) rather than mass-scalable consumer products[7].

2.2. Identifications of VR concepts within entertainment media

Topics of near-future virtual reality technology have been present in entertainment for an extended period. As these concepts become more elaborated, the implementation and the use of future technology might be able to make such progress possible. One possible theoretical use of VR is through Kawahara Reki’s famous light novel series Sword Art Online. Within his works, he expands on his theory labeled “Full Dive” virtual reality, a concept of virtual gameplay that exceeds the technology that we have today.

Through this development, two concepts emerge: Haptic and Full Dive Immersion. Haptic technology implements mobility within the experience of virtual reality where the “player” physically moves his or her body in reaction to the stimulants in the headset (basically the VR headsets of Oculus today)[8]. Through the application of stimulus-based components, such as gloves that can mimic the virtual environment of your head, it creates a more immersive experience through its gameplay. On the other hand, Full Dive Immersion is the concept of directly inputting information into the brain and allowing it to react, without moving the body. It artificially creates a virtual environment and can control what you experience by manipulating the human’s 5 senses.

2.3. Haptics

The first major prominence of haptic technology arose after the popularity of the Oculus Virtual Reality headsets. While we can already see the early development of this technology through the vibrations of console controllers, recent improvements in technology now allow for an almost full immersive experience within the realm of virtual reality. An example of the concept is present in the 2018 film Ready Player One, which is based on Ernest Cline's novel of the same name. In a dystopian world taking place in 2045, people from this story try to escape their poverty-stricken realities through the OASIS (Ontologically Anthropocentric Sensory Immersive Simulation), which is a mass multiplayer virtual reality environment. With their technology, players can touch objects and animate beings as if they were physically present, despite only existing through a virtual medium[9]. By far, this is the closest concept that could be made possible with a few major improvements in our current virtual device technologies. By combining the Virtuix Omni Directional Treadmill and the Oculus Rift, a more immersive experience could be achieved. Although it may not achieve an immersive experience, it is more practical in the sense that it utilizes technology that is not directly interfering with the nerve signals. This, in turn, makes it a more practical way for consumers and a mass-scalable product to the public. The omnidirectional treadmill allows users to physically move their bodies, thus allowing their virtual avatars to move within the virtual space as well, without positionally moving. Like how a regular treadmill is used at gyms so that people can train cardio without translationally moving, it works the same way in the omnidirectional treadmill: the only difference is that the user can move in all 360° of motion. Though it is effective in replicating physical movements of the physical world as it directly translates to the virtual world, it is only best at replicating the physical movements and it is limited in the amount of immersion that it shows, an example which includes swimming, as replicating this with an immersive experience in mind is very hard to replicate.

2.4. Full Dive Immersion

Full Dive Immersion is a concept that is currently unattainable with our current knowledge of the brain and current existing neurotechnology. The concept requires the interception of nerve signals from the brain to the muscles and organs within the body. This intervention of the nerve signals poses a huge health risk to the user as our current technology is incapable of performing such tasks. One possibility that could be reached using improvements in our current technology is the use of neuromodulation which is achieved by using focused ultrasounds[10]. Through this method, scientists can intercept neural signals from the brain, preventing information from reaching different organs and muscles around the body. Using this method inhibits the user's mobility. It is one of the major components that go into making the full dive concept feasible, however, due to the lack of testing and its exclusive availability for medical use, more research and development needs to go into further optimizing this technology. With the use of EEG technology, the brain signals of the user could be read and interpreted. In one experiment, a patient was tasked to move their virtual avatar from one end of the street to the other using only their imagination to visualize the movements. The patient was tetraplegic, yet was able to " control his movements in a [Virtual Environment] by using an asynchronous BCI based on one single EEG recording[11]"

3. OVERVIEW OF NEUROLOGICAL DISORDERS

3.1. Prevalence and Impact:

Neurological disorders encompass a wide range of conditions that affect the brain, spinal cord, and peripheral nerves, leading to disruptions in motor, sensory, cognitive, and behavioral functions. They are highly prevalent worldwide, with millions of individuals affected by conditions such as stroke, Parkinson's disease, multiple sclerosis, epilepsy, and traumatic brain injury. These disorders have a profound impact on a patient's quality of life, often causing physical disabilities, cognitive impairments, emotional disturbances, and social isolation. Neurological disorders encompass a wide range of conditions that affect the brain, spinal cord, and peripheral nerves[12]. They can have profound impacts on individuals' lives, causing disruptions in motor, sensory, cognitive, and behavioral functions. Neurological disorders are prevalent worldwide, affecting millions of people of all ages and demographics. According to the World Health Organization (WHO), it is estimated that over one billion people worldwide suffer from neurological conditions. These disorders can be acquired or genetic, and their prevalence varies across different populations and regions. Certain neurological disorders are more common than others. For example, stroke is a leading cause of disability and death globally, with approximately 15 million people experiencing a stroke each year. Other prevalent conditions include epilepsy, which affects approximately 50 million people worldwide, and Alzheimer's disease, which is the most common form of dementia, affecting over 50 million individuals[13].

3.2. Impact on Individuals and Society

Neurological disorders have a significant impact on individuals' quality of life, as well as on society as a whole. The effects can be far-reaching and multidimensional, affecting various aspects of daily functioning and well-being[12].

1. Physical Impairments: Neurological disorders often lead to physical impairments, such as muscle weakness, paralysis, loss of sensation, and coordination difficulties. These physical limitations can result in challenges with mobility, self-care, and independence.

2. Cognitive and Mental Health Impacts: Many neurological disorders are associated with cognitive impairments, including memory loss, difficulties with attention and concentration, and problems with problem-solving and decision-making. Additionally, individuals may experience mental health issues such as depression, anxiety, and emotional instability, which can further impact their overall well-being[12].

3. Social and Emotional Consequences: The impact of neurological disorders extends beyond the individual, affecting their relationships, social interactions, and emotional well-being. The limitations imposed by these conditions can lead to social isolation, stigma, and reduced quality of life.

4. Economic Burden: Neurological disorders impose a substantial economic burden on individuals, families, and society. The costs associated with medical treatments, medications, assistive devices, rehabilitation services, and long-term care can be significant. Moreover, the indirect costs related to lost productivity, caregiver burden, and decreased workforce participation contribute to the economic impact[12].

3.3. Addressing the Challenges

The prevalence and impact of neurological disorders emphasize the need for effective strategies to address these challenges. Several key approaches can contribute to improving the lives of individuals with neurological conditions[12]:

1. Early Detection and Diagnosis: Timely and accurate diagnosis is crucial for implementing appropriate interventions and treatments. Increased awareness among healthcare professionals and the general public can help in recognizing early signs and symptoms.

2. Accessible and Comprehensive Healthcare Services: There is a need for accessible and affordable healthcare services that provide comprehensive care for neurological disorders. This includes specialized medical professionals, rehabilitation services, mental health support, and assistive technologies.

3. Multidisciplinary Treatment Approaches: The management of neurological disorders often requires a multidisciplinary approach, involving healthcare professionals from various disciplines, including neurologists, physical therapists, occupational therapists, speech therapists, psychologists, and social workers. Collaboration between these professionals can optimize patient outcomes.

4. Research and Innovation: Continued research into the causes, prevention, and treatment of neurological disorders is essential. Advances in technology, such as the implementation of full-dive immersion, offer promising avenues for enhancing therapeutic interventions and improving patient outcomes.

4. TREATMENT APPROACHES

4.1. Conventional Treatment

Current treatment approaches for neurological disorders primarily focus on pharmacological interventions, surgical procedures, and rehabilitative therapies. While these methods can be effective to varying degrees, they often have limitations. Medications may have side effects or be ineffective for certain patients, surgery carries inherent risks, and rehabilitative therapies can be time-consuming and challenging to access. There is a need for innovative approaches that can complement or enhance existing treatments[14].

1. Pharmacological Interventions: Pharmacological interventions play a vital role in the treatment of neurological disorders. Medications are often prescribed to control symptoms, manage disease progression, and prevent complications. The specific drugs used depend on the type and severity of the neurological disorder. For example, antiepileptic drugs are commonly prescribed for epilepsy to reduce the frequency and severity of seizures. In the case of Parkinson's disease, medications such as levodopa are used to restore dopamine levels in the brain and improve motor symptoms. Additionally, antidepressants, anxiolytics, and antipsychotics may be prescribed to manage mental health symptoms associated with certain neurological disorders[15].

2. Surgical Interventions: Surgery is an important treatment option for certain neurological disorders that cannot be effectively managed with medications alone. It aims to alleviate symptoms, remove tumors, repair structural abnormalities, or address specific underlying causes. For instance, deep brain stimulation[16] (DBS) is a surgical procedure used in the treatment of Parkinson's disease, essential tremor, and dystonia. During DBS, electrodes are implanted in specific brain regions to regulate abnormal electrical signals and improve motor symptoms. Similarly, neurosurgical interventions may be performed to remove brain tumors, alleviate pressure on the brain, or manage drug-resistant epilepsy.

3. Rehabilitative Therapies: Rehabilitative therapies are crucial components of the treatment plan for many neurological disorders. These therapies aim to enhance functional abilities, improve mobility, and promote independence. Physical therapy focuses on restoring and improving motor skills, strength, and balance. Occupational therapy aims to help individuals regain skills needed for daily activities, such as dressing, feeding, and bathing. Speech therapy is used to address communication and swallowing difficulties. Rehabilitation programs are tailored to the specific needs of each individual and may include exercises, assistive devices, and adaptive strategies[14].

4. Behavioral and Psychological Interventions: Behavioral and psychological interventions are integral in managing neurological disorders, particularly those involving cognitive and behavioral symptoms. Cognitive-behavioral therapy (CBT) is commonly employed to help individuals cope with emotional challenges, manage stress, and address maladaptive behaviors. It can be beneficial in conditions such as traumatic brain injury, stroke, and multiple sclerosis. Psychoeducation, counseling, and support groups are also important components of comprehensive treatment plans, providing individuals and their families with information, emotional support, and coping strategies[17].

5. Assistive Technologies: Assistive technologies play a significant role in enhancing independence and improving the quality of life for individuals with neurological disorders. These technologies include mobility aids (e.g., wheelchairs, walkers), communication devices (e.g., augmentative and alternative communication systems), and adaptive equipment (e.g., modified utensils, environmental controls). Assistive technologies are designed to address specific functional limitations and promote participation in daily activities[14].

6. Complementary and Alternative Therapies: Complementary and alternative therapies are often used alongside conventional treatments for neurological disorders. These therapies may include acupuncture, yoga, meditation, herbal remedies, and dietary modifications. While scientific evidence for the effectiveness of these interventions is varied, some individuals report symptom relief, improved well-being, and enhanced quality of life. Individuals need to consult with healthcare professionals before incorporating complementary and alternative therapies into their treatment plans[18].

4.2. Limitations of Existing Therapies:

Existing therapies for neurological disorders may fall short in addressing specific challenges. For example, neurorehabilitation often requires repetitive and intensive practice to promote functional recovery, which can be monotonous and demotivating for patients. Additionally, managing chronic pain associated with neurological conditions can be complex, with limited non-pharmacological options available. Psychological support and mental health management are also essential aspects that may be overlooked in traditional treatment approaches[19].

1. Symptomatic Treatment: Many existing therapies for neurological disorders primarily focus on managing symptoms rather than addressing the underlying causes. While symptomatic relief is essential for enhancing the quality of life, it does not necessarily halt or reverse the progression of the disorder. This limitation is particularly evident in conditions such as Alzheimer's disease, Parkinson's disease, and multiple sclerosis, where current therapies primarily aim to alleviate symptoms rather than provide a definitive cure[15].

2. Lack of Disease-Modifying Treatments: A significant challenge in treating neurological disorders is the absence of disease-modifying treatments. While some therapies may help manage symptoms and slow down disease progression to some extent, they do not halt or reverse the underlying pathological processes. This limitation underscores the need for innovative research and the development of therapies that target the fundamental causes of neurological disorders, such as neuroprotective agents or interventions aimed at promoting neuroregeneration[15].

3. Individual Variability in Treatment Response: Neurological disorders often exhibit significant heterogeneity in terms of clinical presentation, disease progression, and treatment response among individuals. What works for one person may not be effective for another, making it challenging to provide standardized and universally effective treatment approaches. This highlights the importance of personalized medicine and the need to identify biomarkers and genetic factors that can guide treatment decisions and predict individual responses to therapies[15].

4. Limited Access to Specialized Care: Access to specialized neurological care, including neurologists, neurosurgeons, and rehabilitation professionals, can be limited in certain regions, especially in low-resource settings. This limitation hampers the delivery of optimal care and timely interventions for individuals with neurological disorders. Addressing the lack of specialized care requires efforts to improve healthcare infrastructure, increase healthcare workforce capacity, and develop telemedicine and remote care solutions to bridge geographical gaps[7].

5. Side Effects and Safety Concerns: Pharmacological interventions, a common treatment modality for neurological disorders, often come with side effects and safety concerns. Medications may cause adverse reactions, drug-drug interactions, or long-term complications. Balancing the potential benefits of pharmacotherapy with its associated risks requires careful consideration, monitoring, and individualized treatment plans. Minimizing side effects and optimizing the safety profiles of medications remain important areas of research and development[15].

6. Limited Efficacy in Progressive Disorders: Neurological disorders with progressive courses, such as amyotrophic lateral sclerosis (ALS) or Huntington's disease, pose unique challenges for therapeutic interventions. While some treatments may offer temporary relief or slow down disease progression in the early stages, they often face diminishing efficacy as the disease advances. Addressing the limitations of existing therapies in progressive disorders necessitates ongoing research to identify novel targets, develop disease-modifying approaches, and explore combination therapies[20].

7. Psycho-social Support and Holistic Care: Neurological disorders impact physical functioning and have profound psycho-social implications. Many existing therapies focus primarily on the physical aspects of care, potentially neglecting the psychological, emotional, and social needs of individuals and their caregivers. Comprehensive care should include psycho-social support, mental health interventions, and educational resources to help patients and their families cope with the psychological burdens associated with neurological disorders[17].

4.3. Full Dive Immersion and Neurological Disorders:

Full dive immersion has the potential to leverage the brain's neuroplasticity and promote functional recovery by providing intensive and engaging therapeutic experiences. Creating virtual environments that stimulate specific neural pathways, may facilitate motor relearning, sensory integration, and cognitive rehabilitation. The immersive nature of full dive technology may also help in pain modulation, relaxation, and emotional regulation, offering holistic approaches to neurological disorder management[21].

1. Sensorimotor Integration: One of the key mechanisms by which full dive immersion can benefit individuals with neurological disorders is through sensorimotor integration. Neurological conditions often result in disruptions in sensory processing and motor control. By providing a realistic virtual environment that stimulates various sensory inputs, including visual, auditory, and haptic feedback, full dive immersion can help reestablish and enhance sensorimotor integration. This immersive experience can improve motor function, spatial awareness, and coordination, promoting neuroplasticity and facilitating the relearning of movement patterns[21].

2. Cognitive Stimulation: Full dive immersion has the potential to provide intensive cognitive stimulation for individuals with neurological disorders. Virtual environments can be designed to engage specific cognitive processes, such as attention, memory, problem-solving, and decision-making. By presenting interactive tasks and challenges within the virtual environment, full dive immersion can promote cognitive engagement and rehabilitation. This cognitive stimulation can facilitate neuronal connections, enhance cognitive functioning, and potentially slow down cognitive decline in conditions such as Alzheimer's disease and traumatic brain injury[11].

3. Emotional Regulation and Psychological Well-being: Neurological disorders often have a significant impact on emotional regulation and psychological well-being. Full dive immersion can offer a therapeutic tool to address these aspects. Virtual environments can be designed to evoke specific emotional states or provide exposure therapy for individuals with anxiety or phobias. By creating controlled and safe virtual scenarios, full dive immersion can help individuals manage their emotional responses, desensitize fears, and improve emotional regulation. This immersive experience can contribute to overall psychological well-being, reducing stress, and improving quality of life[17].

4. Rehabilitation and Neuroplasticity: Full dive immersion has the potential to enhance rehabilitation and promote neuroplasticity in individuals with neurological disorders. By creating immersive and engaging environments, full dive immersion can motivate individuals to actively participate in therapeutic exercises and rehabilitation programs. Virtual reality-based interventions can offer feedback, rewards, and real-time performance monitoring, making rehabilitation more enjoyable and enhancing motivation. Through repetitive and targeted training, full dive immersion can facilitate neuroplastic changes, promote neural reorganization, and optimize functional recovery[15].

5. Social Interaction and Empathy: Neurological disorders often lead to social isolation and difficulties in social interaction. Full dive immersion can address these challenges by providing virtual environments that facilitate social interaction and enhance empathy. Virtual reality platforms can enable individuals with neurological disorders to engage in social activities,

participate in group therapy sessions, and interact with virtual avatars or real-life individuals. This immersive social experience can improve social skills, increase confidence, and reduce feelings of isolation[17].

4.4. Therapeutic Applications:

Full dive immersion can provide a highly engaging and interactive platform for neurorehabilitation. Virtual reality simulations can be tailored to target specific motor or cognitive deficits, allowing patients to practice movements, improve coordination, and enhance cognitive skills in a safe and controlled environment[21].

1. Motor Rehabilitation: Motor rehabilitation is a critical aspect of neurorehabilitation, aiming to restore or enhance motor function in individuals with neurological disorders. Full dive immersion provides a platform that can simulate real-world movements and activities within a safe and controlled virtual environment. Through the use of motion tracking devices and haptic feedback, individuals can engage in virtual exercises and rehabilitation activities that target specific motor skills. The immersive nature of the virtual environment enhances engagement and motivation, facilitating neuroplastic changes and motor skill acquisition[21].

2. Cognitive Rehabilitation: Cognitive impairments are commonly associated with neurological disorders, affecting various domains such as attention, memory, executive functions, and problem-solving. Full dive immersion can be utilized to provide intensive cognitive rehabilitation interventions. Virtual reality environments can be designed to stimulate specific cognitive processes and challenge individuals to perform tasks that target their cognitive deficits. For example, virtual reality-based memory training programs can improve memory encoding and retrieval in individuals with traumatic brain injury or dementia. The immersive and interactive nature of the virtual environment enhances cognitive engagement and facilitates neural plasticity[21].

3. Sensory Integration: Neurological disorders often involve disruptions in sensory processing, leading to difficulties in integrating and interpreting sensory information. Full dive immersion offers a unique opportunity to address sensory integration challenges. Virtual reality environments can be designed to provide multisensory stimulation, combining visual, auditory, and haptic feedback. By creating realistic and immersive sensory experiences, full dive immersion can help individuals retrain their sensory processing systems, improve sensory integration, and enhance overall perception and awareness[22].

4. Psychological Interventions: Psychological well-being plays a crucial role in the rehabilitation process for individuals with neurological disorders. Full dive immersion can be utilized to provide therapeutic interventions that target psychological factors such as anxiety, depression, and emotional regulation. Virtual reality environments can offer exposure therapy for phobias and anxiety disorders, providing a safe and controlled setting for individuals to confront their fears. Additionally, virtual reality-based relaxation and mindfulness programs can help reduce stress, promote emotional regulation, and improve overall psychological well-being[22].

5. Functional Rehabilitation: Full dive immersion can also facilitate functional rehabilitation, focusing on improving individuals' ability to perform activities of daily living and promoting their independence. Virtual reality simulations can recreate real-life scenarios, such as cooking, shopping, or using public transportation, allowing individuals to practice and improve their functional skills in a virtual environment. By providing a realistic and interactive setting, full dive immersion can enhance confidence, problem-solving abilities, and functional performance in individuals with neurological disorders[21].

6. Accessibility and Personalization: One of the significant advantages of full dive immersion in neurorehabilitation is its potential for accessibility and personalization. Virtual reality-based interventions can be tailored to the specific needs and abilities of individuals, providing a customizable and adaptive rehabilitation experience. Additionally, full dive immersion can overcome physical barriers by creating virtual environments that simulate real-world activities and interactions. This accessibility allows individuals with mobility limitations or geographical constraints to engage in immersive rehabilitation programs[21].

5. CONCLUSION

Full dive immersion holds significant therapeutic potential in the field of neurorehabilitation. Through its unique ability to create immersive and interactive virtual environments, it provides a platform for motor rehabilitation, cognitive rehabilitation, sensory integration, psychological interventions, functional rehabilitation, and personalized rehabilitation experiences. Further research is needed to validate full dive immersion and optimize its design. Enhanced sensory feedback systems are anticipated, incorporating haptic, olfactory, and taste sensations for more realistic experiences. Integrating brain-computer interfaces (BCIs) can revolutionize full dive immersion, allowing users to control virtual environments with their thoughts. This benefits individuals with motor disabilities, providing new opportunities for interaction. Future developments may focus on simulating complex social interactions, enabling realistic therapy, training, and entertainment experiences. Augmented reality (AR) integration can blend virtual and real-world elements, expanding possibilities for education, training, and therapy. Full dive immersion has significant potential in healthcare, including pain management, phobia treatment, surgical simulations, and telemedicine. Advancements in display technology, such as higher resolution and wider field-of-view, will enhance immersion. Lightweight and compact devices will improve comfort and accessibility. The future of full dive immersion relies on these advancements and their applications.

REFERENCES

[1] M. X. Cohen, "Where does EEG come from and what does it mean?," *Trends in Neurosciences*, vol. 40, no. 4, pp. 208–218, 2017. doi:10.1016/j.tins.2017.02.004

[2] M. Ienca and R. Andorno, "Towards new human rights in the age of neuroscience and Neurotechnology," *Life Sciences, Society and Policy*, vol. 13, no. 1, 2017. doi:10.1186/s40504-017-0050-1

[3] Jean-Pascal Lefaucheur a b et al., "Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rtms)," Clinical Neurophysiology, https://www.sciencedirect.com/science/article/abs/pii/S1388245714 00296X?via%3Dihub (accessed Jun. 13, 2023).

[4] J.-D. Haynes *et al.*, "Reading hidden intentions in the human brain," *Current Biology*, vol. 17, no. 4, pp. 323–328, 2007. doi:10.1016/j.cub.2006.11.072

[5] B. J. C. Yuan, C. H. Hsieh, and C. C. Chang, "National Technology Foresight Research: A literature review from 1984 to 2005," *International Journal of Foresight and Innovation Policy*, vol. 6, no. 1/2/3, p. 5, Apr. 2010. doi:10. 1504/ijfip.2010.032663

[6] M. O. Baud *et al.*, "Multi-day rhythms modulate seizure risk in epilepsy," *Nature Communications*, vol. 9, no. 1, 2018. doi:10.1038/s41467-017-02577-y

[7] D. A. Borton, H. E. Dawes, G. A. Worrell, P. A. Starr, and T. J. Denison, "Developing collaborative platforms to advance neurotechnology and its translation," *Neuron*, vol. 108, no. 2, pp. 286–301, Oct. 2020. doi:10.1016/j.neuron. 2020.10.001

[8] M. Xu et al., "A Full Dive Into Realizing the Edge-Enabled Metaverse: Visions, Enabling Technologies, and Challenges," in IEEE Communications Surveys & Tutorials, vol. 25, no. 1, pp. 656-700, Firstquarter 2023, doi: 10.11 09/COMST.2022.3221119.

[9] E. Cline and A. R. van der, *Ready Player One*. Amsterdam: Q, 2018.

[10] "Parkinson's disease," Focused Ultrasound Foundation, https://www.fusfoundation.org/diseases-and-conditions/ parkinsons-disease/ (accessed Jun. 13, 2023).

[11] A. Lecuyer *et al.*, "Brain-computer interfaces, virtual reality, and Videogames," *Computer*, vol. 41, no. 10, pp. 66–72, 2008. doi:10.1109/mc.2008.410

[12] "Disease control priorities related to mental, neurological, developmental and substance abuse disorders," Google Books, https://books.google.com/books?hl=en&lr=&id=zsVMBTF8vREC&oi=fnd&pg=PA21&dq=neurological%2Bdisorders&ots=ra_DlOSQhS&sig=rEsPbNaPM_4GcNbU2mhNmg6Wo1U#v=onepage&q=neurological%20disorders&f=false (accessed Jun. 13, 2023).

[13] "Neurological disorders affect millions globally: Who report," World Health Organization, https://www.who.int/ news/item/27-02-2007-neurological-disorders-affect-millions-globally-who-report (accessed Jun. 13, 2023).

[14] A. M. Barrett, M. Oh-Park, P. Chen, and N. L. Ifejika, "Neurorehabilitation: Five new things," *Neurology: Clinical Practice*, vol. 3, no. 6, pp. 484–492, 2013. doi:10.1212/01.cpj.0000437088.98407.fa

[15] R. Szelenberger, J. Kostka, J. Saluk-Bijak, and E. Miller, "Pharmacological interventions and rehabilitation approach for enhancing brain self-repair and stroke recovery," *Current Neuropharmacology*, vol. 18, no. 1, pp. 51–64, 2019. doi:10.2174/1570159x17666190726104139

[16] J. S. Perlmutter and J. W. Mink, "Deep brain stimulation | annual review of neuroscience," Annual Reviews, https://www.annualreviews.org/doi/abs/10.1146/annurev.neuro.29.051605.112824 (accessed Jun. 14, 2023).

[17] M. Nakao, K. Shirotsuki, and N. Sugaya, "Cognitive–behavioral therapy for management of mental health and stress-related disorders: Recent advances in techniques and technologies," *BioPsychoSocial Medicine*, vol. 15, no. 1, 2021. doi:10.1186/s13030-021-00219-w

[18] "Complementary & Alternative Therapies in neurology," Minneapolis Clinic of Neurology, https://minneapolisclinic.com/patient-resources/complementary-alternative-therapies-in-neurology/ (accessed Jun. 13, 2023).

[19] P. Krack, R. Martinez-Fernandez, M. del Alamo, and J. A. Obeso, "Current applications and limitations of surgical treatments for movement disorders," *Movement Disorders*, vol. 32, no. 1, pp. 36–52, 2017. doi:10.1002/mds.26890

[20] S. Dhasmana *et al.*, "The panoramic view of amyotrophic lateral sclerosis: A fatal intricate neurological disorder," *Life Sciences*, vol. 288, p. 120156, 2022. doi:10.1016/j.lfs.2021.120156

[21] O. O'Neil *et al.*, "Virtual reality for neurorehabilitation: Insights from 3 European clinics," *PM&R*, vol. 10, 2018. doi:10.1016/j.pmrj.2018.08.375

[22] L. A. Brenner, S. A. Reid-Arndt, T. R. Elliott, R. G. Frank, and B. Caplan, *Handbook of Rehabilitation Psychology*. Washington, DC: American Psychological Association, 2019.