IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Transcranial Direct Current Stimulation Versus Virtual Reality On Post-Stroke Depression: A Randomised Clinical Trial

[1]Aaliya Sayad, [2]Raghavendrasingh Dharwadkar

[1]Post Graduate student, [2]Assistant professor

[1]Neurology physiotherapy,

[1]KAHER Institute of Physiotherapy

Abstract: **Introduction**: Post-stroke depression (PSD) is one of the most common complications of stroke with a prevalence of 55%. It limits the recovery of a patient's motor and cognitive functions and also affects the rehabilitation and quality of life. The present study aims to compare the effect of Transcranial Direct Current Stimulation and Virtual Reality on Post-Stroke Depression.

Methods and materials: In this study 20 participants were included and were randomized into two groups. Stroke patients with post-stroke depression between the age group of 21-75 years old of both genders were included. They were allocated to two groups ie. Virtual Reality coupled with conventional physiotherapy (Group A) and Transcranial Direct Current Stimulation coupled with conventional physiotherapy (Group B) by envelope method. The primary outcome measure was the Hamilton Depression Rating Scale (HDRS) and the secondary outcome measures were the Montreal Cognitive Assessment Scale (MOCA) and Functional Independence Measure (FIM).

Results: Statistical analysis showed significant improvement across all measures in both groups. However, participants in the VR group demonstrated greater reductions in depression scores, enhanced cognitive performance, and improved functional independence compared to those receiving tDCS.

Conclusion: The present study concluded that Virtual Reality improved post-stroke depression, cognitive function, and activities of daily living (ADLs) in patients with post-stroke depression

Keywords: Post-stroke depression, Transcranial Direct Current Stimulation, Virtual Reality, Subacute and Chronic Stroke.

I. Introduction

In 1970, the definition of stroke was established by the World Health Organization as the manifestation of swiftly emerging clinical indicators of focal (or global) disruption in cerebral functionality, persisting for a duration exceeding 24 hours or culminating in fatality, without any evident etiology apart from being vascular. (1) The long-term effects of stroke such as cognitive deficits, bowel and urine incontinence, musculoskeletal consequences like shoulder discomfort in hemiplegia, spasticity, stiffness and hypertonicity, emotional lability, and post-stroke depression are been neglected. (3) Roughly thirty percent of stroke victims experience post-stroke depression. (4) A lower quality of life (5), a higher death rate (6), and worse functional results [7] are all linked to depression following a stroke. Factors such as genetics, gender, age, medical and psychiatric history, severity of stroke, type of stroke, lesion site, social support, and level of disability, have been identified as risk factors connected to the emergence of depression following a stroke. [8] An overlooked association exists between depression and cognitive dysfunction during the initial three months after a stroke. [9] Patients with more severe depression were shown to have cognitive impairment three times more frequently than those with milder symptoms. [9] In most cases, Post-stroke depression is a curable disorder. Pharmacological, psychological, and stroke-specific treatments are combined to produce the best therapeutic outcomes. [10] Transcranial Direct Current Stimulation (tDCS) is a type of non-invasive brain stimulation technique that entails delivering a mild electrical current directly to the scalp using electrodes. [11] Excitability of the motor cortex is increased by anodal stimulation and decreased by cathodal stimulation. [12] Synaptic plasticity is altered in response to alterations in cortical excitability brought on by tDCS. These alterations affect cortical function and enhance cognitive capacities. [13] Various attributes such as, the absence of pharmacokinetic interactions, noninvasiveness, tolerability, and safety make Transcranial Direct Current Stimulation (tDCS) a valuable modality for mental disorders. [14 Recent research has demonstrated the efficacy of Transcranial Direct Current Stimulation (tDCS) in addressing various medical conditions, including mood disorders and motor and cognitive impairments post-stroke. [15] Possibly one of the most intriguing new technologies being utilized to address depression and anxiety is Virtual Reality (VR). [16] VR exposure therapy (VRET) is a form of exposure treatment that adheres to the same guidelines as traditional exposure therapy, with the exception that the feared scenarios or objects are placed within a virtual world. [17] The most pertinent uses of VR technology for the treatment of depression, according to recent scoping assessments, involve the creation of immersive virtual rooms that also meet the requirements of psychiatric assessment. [18] Based on current understanding and a thorough search of the literature, no research has compared the effects of Virtual Reality and Transcranial Direct Current Stimulation on depression following a stroke, and were done over extended periods of time. The purpose of this study is to compare the effects of Virtual Reality and Transcranial Direct Current Stimulation on depression following a stroke and determine which treatment strategy shows faster results.

II. METHODS

The study was a single-blinded, randomized clinical trial conducted at Tertiary care Hospital, Belagavi, Karnataka, India after obtaining the Ethical Approval from Research and Ethical Committee between October 2024 to March 2024. Every participant in the study gave their informed consent after it was authorized by the Institutional Ethical Board Committee.

Subjects were taken from various tertiary hospitals across Belagavi city. 37 individuals were evaluated for post stroke depression. Out of which 17 participants did not meet the inclusion criteria and so were excluded. The 20 subjects were recruited and randomly allocated by envelope method to Group A (n=10) Virtual Reality and group 2 (n=10) Transcranial Direct Current Stimulation. The inclusion criteria were: individuals 45 years of age or older, with mild to moderate depression on the Hamilton depression rating scale, a score of less than 26 on Montreal cognitive assessment scale, and a score of less than 5 on Functional independence measure, regardless of gender while the exclusion criteria was medically unstable patients, epilepsy, bipolar disorder, psychiatric disorder, motion sickness, active nausea, hearing impairment, vomiting and loss of vision, presence of any materials within the body such as pacemakers, dentures, metal prosthesis and participants receiving psychological treatment

Group A: patients were made to wear a headset display to start the VR (Figure 1). The immersive 360º videos were shown to the patient with the head-mounted display. The patient was advised to move his head and body while watching the video without standing, as a safety measure. It will be delivered for 20 minutes 5 times per week for 2 weeks and 30 minutes of conventional therapy. [19]

Group B: Anodal tDCS (2 mA intensity) was delivered for 30 minutes through electrodes soaked with saline solution. The anode was placed at position F3 in the international 10/20 system, targeting the left dorsolateral prefrontal cortex. Conversely, the cathode was positioned at F4, corresponding to the right dorsolateral prefrontal cortex (Figure 2). It was delivered for 30 minutes, 5 times a week for 2 weeks with 30 minutes of conventional therapy. [20]

Conventional therapy**:** Neuroinhibitory techniques, Range of motion exercises, Balance exercises, Strengthening exercises, and Aerobic exercises.

Participants were evaluated two times: Before the intervention and 2 weeks after the intervention. The Hamilton depression rating scale (HDRS) was the primary outcome measure. The secondary outcomes were the Montreal Cognitive Assessment Scale and the functional independence measure.

Figure 1- virtual reality

Figure 2- Transcranial Direct Current Stimulation

Statistical analysis: Data were analyzed using the SPSS version 23. The gathered data was consolidated through the utilization of descriptive statistics, including frequency, percentage, mean, and standard deviation. The Shapiro-Wilk test was employed to assess the normal distribution of the dataset. An independent t-test was utilized to examine the age differences between the two distinct groups. A paired sample t-test was conducted to analyze the pre-test and post-test comparisons of the Hamilton Depression Rating Scale, Montreal Cognitive Assessment Scale, and Functional Independence Measure. The p-value <0.05 was considered significant

III. **Results:** In our study 37 subjects were evaluated for post stroke depression. Out of which 17 subjects did not meet the inclusion criteria and so were excluded. The 20 subjects were recruited and randomly allocated to Group A (n=10) Virtual Reality and group 2 (n=10) Transcranial Direct Current Stimulation. (Figure 3)

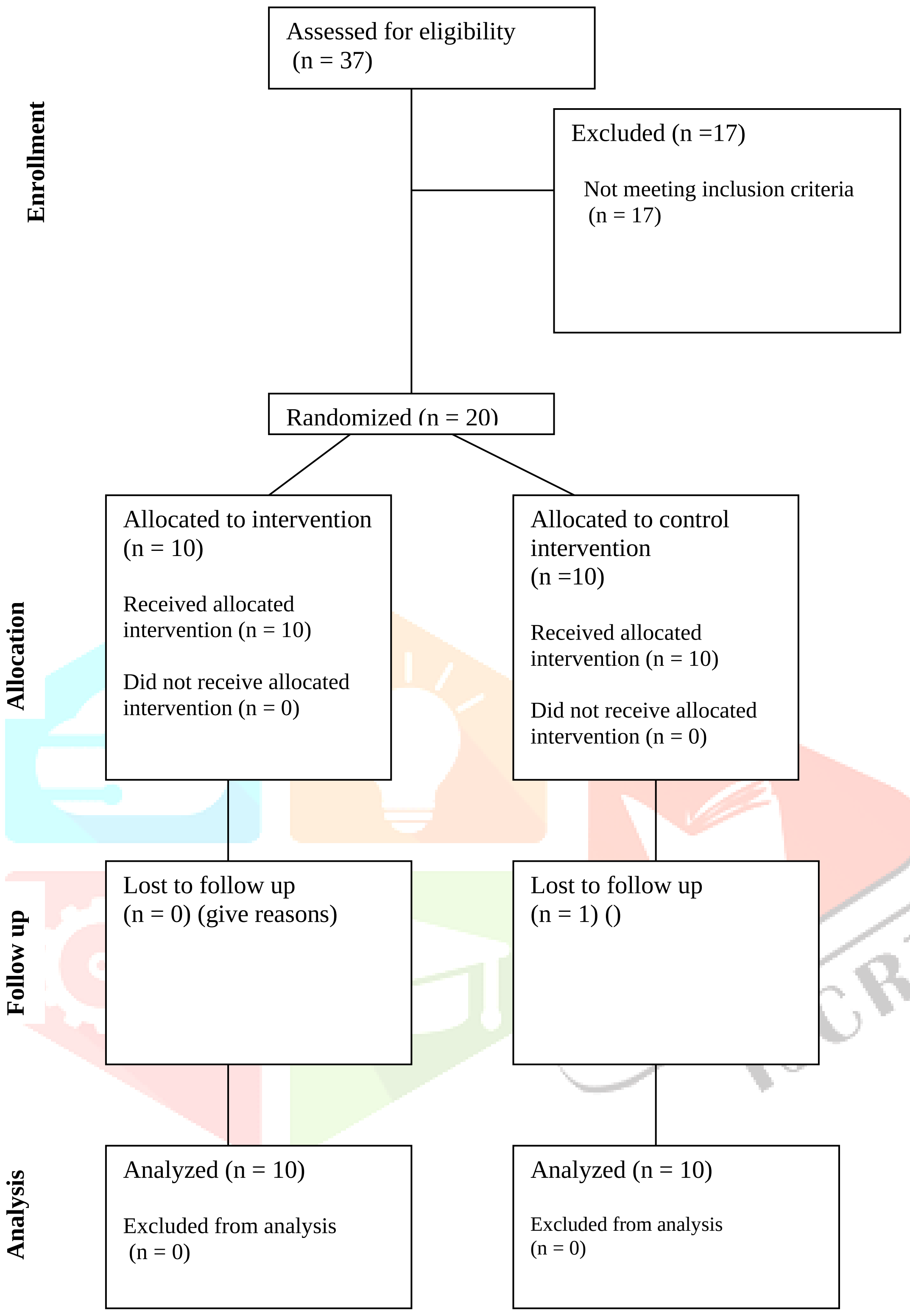

Figure 3- Consort chart

Post-stroke depression was assessed using the Hamilton depression rating scale (HDRS). The average score on the Hamilton Depression Rating Scale (HDRS) at the initial assessment was recorded as 19.40 which changed to 13.60 in the Virtual Reality group. While the mean score on HDRS at baseline was 19.70 which changed to 17.70 in the Transcranial Direct Current Stimulation group. Thus significant differences were observed in group A with a p-value of 0.001.

Cognition was assessed using the Montreal Cognitive Assessment Scale (MOCA). The mean score on MOCA at baseline was 18.20 which increased to 23.30 in group A. while it was 16.90 at baseline which increased up to 18.60 in group B. The table presented above indicates a statistically significant difference in between-groups analysis for the Montreal Cognitive Assessment Scale.

Functional outcomes were assessed using the functional independence measure (FIM). The mean score at baseline was 66.70 which increased to 78.40 in Group A while it was 57.30 which increased to 58.70 in Group B. The table presented above demonstrates a significant difference in between-group analysis for the Functional Independence Measure. (Table 1)

Variable	Time	Group	Mean	SD	t-value	p-value
Hamilton Depression Scale	Pre	Group A	19.40	3.03	0.253	0.803
		Group B	19.70	2.21		
	Post	Group A	13.60	2.12	**4.700**	**0.001**
		Group B	17.70	1.77		
Montreal Cognitive Assessment Scale	Pre	Group A	18.20	1.69	1.671	0.112
		Group B	16.90	1.79		
	Post	Group A	23.30	2.11	**5.932**	**0.001**
		Group B	18.60	1.35		
Functional Independence Measure	Pre	Group A	66.70	7.01	**2.602**	**0.018**
		Group B	57.30	9.02		
	Post	Group A	78.40	4.55	**8.491**	**0.001**
		Group B	58.70	5.76		

Table 1: Comparison between groups
*p<0.005= statistically significant

When baseline and post-intervention values were compared, within-group analysis reveals significant improvements in all outcome measures in both groups (Table 2)

Table 2- within group analysis

HDRS	Group A	Pre	19.40	3.03	5.80	1.62	3.58	11.326	0.001
		Post	13.60	2.12					
	Group B	Pre	19.70	2.21	2.00	0.94	2.12	6.708	0.001
		Post	17.70	1.77					
MOCA	Group A	Pre	18.20	1.69	5.10	1.37	3.72	11.769	0.001
		Post	23.30	2.11					
	Group B	Pre	16.90	1.79	1.70	0.67	2.52	7.965	0.001
		Post	18.60	1.35					
FIM	Group A	Pre	66.70	7.01	11.70	4.00	2.92	9.246	0.001
		Post	78.40	4.55					
	Group B	Pre	57.30	9.02	1.40	7.83	0.18	0.565	0.586
		Post	58.70	5.76					

*p<0.005= statistically significant

IV. DISCUSSION:

The present randomized clinical trial aimed to compare the effects of Virtual Reality (VR) therapy and Transcranial Direct Current Stimulation (tDCS) on post-stroke depression. Our findings suggest that VR therapy, when delivered over ten sessions, produced a greater reduction in depressive symptoms, improved cognitive functioning, and enhanced functional independence compared to an equivalent schedule of tDCS. This study adds to the growing body of evidence supporting the use of VR and non-invasive brain stimulation techniques in neurorehabilitation. Virtual reality and transcranial direct current stimulation have shown positive effects on post stroke depression in previous studies. [19,20,21]

Virtual Reality has been increasingly explored as a non-pharmacological tool for the management of mood disorders. VR promotes emotional regulation by stimulating the release of endorphins and dopamine, fostering positive emotional states and reducing the burden of negative affect. [22]

In our study, patients exposed to VR therapy demonstrated significant improvements in depression scores, which is consistent with previous research conducted by Pawel Kiper et al. in the year 2022

where fully immersive VR interventions significantly reduced depressive symptoms in post-stroke patients after only 20-minute sessions. The authors, however, called for research exploring alternative VR modalities beyond total immersion, a gap addressed in the current study by using VR combined with conventional physiotherapy rather than fully immersive systems. [21] Additionally, VR offers multimodal stimulation, combining visual, auditory, and proprioceptive inputs to create realistic yet controlled environments that stimulate neural pathways associated with mood and cognitive function. [19]

Studies by Jeffrey M. Rogers et al. in the year 2019 further support these findings, showing that VR interventions significantly improved motor and cognitive outcomes after stroke, even when applied intermittently over a four-week period. Our study mirrors these results, as patients in the VR group demonstrated not only reductions in depressive symptoms but also notable gains in cognitive assessment scores measured by the Montreal Cognitive Assessment (MoCA). [23]

Furthermore, VR has shown benefits beyond post-stroke depression. For example, a research done by Modrego-Alarcón M et al. in the year 2021 found that VR mindfulness meditation programs reduced depression and anxiety among university students during the COVID-19 pandemic. [24]

Similarly, a metanalysis was conducted by Kothgassner OD et al. in the year 2019 highlighted VR's effectiveness in alleviating depressive and anxiety symptoms among individuals with post-traumatic stress disorder (PTSD). These findings suggest that VR can be an adaptable, versatile intervention across various patient populations experiencing mood disturbances. [25]

Nevertheless, the use of VR is not universally effective across all conditions. A systematic review done by Rowland DP et al. in the year 2022 noted that patient engagement and motivation are critical mediators of VR therapy success, and that individuals with severe apathy or disengagement may derive less benefit. (26)

Similarly, a Systematic review and meta analysis was conducted by Cuperus et al. in the year 2019 found that while VR exposure therapy improved PTSD symptoms, its effects on co-occurring depression were less robust. These mixed results emphasize that although VR holds considerable promise, careful patient selection, and individualized therapy planning are essential to optimize outcomes. [27]

In contrast to VR, tDCS has been widely studied for its potential to modulate cortical excitability and neuroplasticity. By applying weak direct electrical currents, tDCS influences the activity of sodium-calcium channels and NMDA receptors, affecting neuroplastic processes critical for mood regulation. [28]

Our study found that the tDCS group experienced modest improvements in functional independence but did not show significant changes in depression scores within the two-week intervention period.

This finding contrasts with results from longer-duration studies. For instance, Leandro Valiengo et al. in the year 2017 conducted a randomized controlled trial administering twelve sessions of tDCS over six weeks, reporting significant reductions in post-stroke depression severity. The shorter treatment duration in our study—only ten sessions over two weeks—likely contributed to the lack of significant improvement in depression outcomes in the tDCS group. [20]

Previous research has highlighted the potential of tDCS to facilitate motor and cognitive recovery after stroke. For instance, Hummel F et al. in the year 2005 demonstrated that anodal tDCS applied over the motor cortex enhanced motor function in chronic stroke patients, with improvements sustained for weeks post-intervention. (29)

Similarly, Lindenberg et al. in the year 2010 reported that combining tDCS with motor training significantly improved upper limb function in individuals with stroke-related impairments. (30)

Moreover, Bolognini et al. in the year 2011 found that bi-hemispheric tDCS targeting the motor cortex promoted better functional outcomes compared to conventional physiotherapy alone. (31)

These findings align with the functional improvements observed in the tDCS group in our study, suggesting that while short-term tDCS may have limited effects on mood, it may positively impact neuroplasticity related to motor and cognitive domains. It also emphasizes that the primary benefits of tDCS could manifest more prominently in functional rather than emotional recovery when applied over shorter durations.

Thus, although VR demonstrated superior outcomes in reducing depressive symptoms, tDCS showed potential advantages in enhancing functional independence, supporting its continued exploration as a valuable adjunct in post-stroke rehabilitation.

Thus, while both VR and tDCS have shown potential benefits in alleviating post-stroke depression, our findings indicate that VR therapy, when combined with conventional physiotherapy, results in faster and more pronounced improvements in mood, cognitive abilities, and activities of daily living. VR provides an engaging, patient-centered approach that enhances rehabilitation adherence and motivation, critical factors for sustained recovery

V. LIMITATIONS

There are a few limitations to the study. Firstly, a smaller sample size was used as many recruited patients did not meet the inclusion criteria. Second, the study was conducted in a specific geographic region, limiting the generalisability of the findings to broader populations with different healthcare systems, cultural influences, and rehabilitation facilities. The study did not include a follow-up assessment, leaving it unclear whether the observed improvements in depression, cognition, and functional independence were maintained over time. Although both Virtual Reality and Transcranial Direct Current Stimulation demonstrated positive effects after two weeks, the lack of long-term data limits the understanding of their sustained impact on post-stroke depression. In order to evaluate the longevity of therapy benefits and identify the ideal frequency of interventions for long-term healing, future studies should include longer follow-up periods.

VI. CLINICAL IMPLICATIONS

The findings of this research have considerable clinical significance. VR can be integrated into standard rehabilitation protocols for PSD. Since antidepressants are frequently used to treat PSD, non-invasive, drug-free alternatives like VR lower the possibility of adverse drug reactions. When compared to passive treatments, VR-based rehabilitation improves patient motivation and adherence, which may result in superior long-term recovery outcomes.

VII. CONCLUSION

The present study concluded that there is a significant improvement in the Hamilton depression rating scale, Montreal cognitive assessment scale, and functional independence measure in group A ie Virtual Reality compared to group B ie. Transcranial Direct Current Stimulation.

VIII. REFERENCES:

1. Aho K, Harmsen P, Hatano S, Marquardsen J, Smirnov VE, Strasser T. Cerebrovascular disease in the community: results of a WHO collaborative study. Bulletin of the World Health Organization. 1980;58(1):113

2. Murphy SJ, Werring DJ. Stroke: causes and clinical features. Medicine. 2020 Sep 1;48(9):561-6

3. Chohan SA, Venkatesh PK, How CH. Long-term complications of stroke and secondary prevention: an overview for primary care physicians. Singapore medical journal. 2019 Dec;60(12):616

4. Ayerbe L, Ayis S, Wolfe CD, Rudd AG. Natural history, predictors and outcomes of depression after stroke: systematic review and meta-analysis. The British Journal of Psychiatry. 2013 Jan;202(1):14-21.

5. Kim ES, Kim JW, Kang HJ, et al. Longitudinal impact of depression on quality of life in stroke patients. Psychiatry Investig 2018;15:141–6

6. Bartoli F, Lillia N, Lax A, et al. Depression after stroke and risk of mortality: a systematic review and meta-analysis. Stroke Res Treat 2013;2013:862978

7. Kutlubaev MA, Hackett ML. Part II: predictors of depression after stroke and impact of depression on stroke outcome: an updated systematic review of observational studies. Int J Stroke 2014;9:1026–36

8. Robinson RG, Jorge RE. Post-stroke depression: a review. American Journal of Psychiatry. 2016 Mar 1;173(3):221-31.

9. Hommel M, Carey L, Jaillard A. Depression: cognition relations after stroke. International Journal of Stroke. 2015 Aug;10(6):893-6

10. Medeiros GC, Roy D, Kontos N, Beach SR. Post-stroke depression: a 2020 updated review. General hospital psychiatry. 2020 Sep 1;66:70-80

11. Wagner T, Valero-Cabre A, Pascual-Leone A. Noninvasive human brain stimulation. Annu. Rev. Biomed. Eng.. 2007 Aug 15;9:527-65.

12. Nitsche MA, Paulus W. Excitability changes induced in the human motor cortex by weak Transcranial Direct Current Stimulation. The Journal of physiology. 2000 Sep 9;527(Pt 3):633.

13. Stagg CJ, Antal A, Nitsche MA. Physiology of Transcranial Direct Current Stimulation. The journal of ECT. 2018 Sep 1;34(3):144-52

14. Brunoni AR, Nitsche MA, Bolognini N, Bikson M, Wagner T, Merabet L, Edwards DJ, Valero-Cabre A, Rotenberg A, Pascual-Leone A, Ferrucci R. Clinical research with Transcranial Direct Current Stimulation (tDCS): challenges and future directions. Brain stimulation. 2012 Jul 1;5(3):175-95

15. Shiozawa P, Fregni F, Benseñor IM, Lotufo PA, Berlim MT, Daskalakis JZ, Cordeiro Q, Brunoni AR. Transcranial Direct Current Stimulation for major depression: an updated systematic review and meta-analysis. International Journal of Neuropsychopharmacology. 2014 Sep 1;17(9):1443-52

16. Lin A, Cheng F, Chen C. Use of Virtual Reality games in people with depression and anxiety. In: Proceedings of the 5th International Conference on Multimedia and Image Processing. 2020 Presented at: ICMIP 2020: 2020 5th International Conference on Multimedia and Image Processing; January 10 - 12, 2020; Nanjing China p. 169-174

17. supporting the treatment of depression and anxiety: Scoping review. JMIR mental health. 2021 Sep 23;8(9):e29681

18. Borisova N, Moore N, Sira Mahalingappa S, Cumming P, Dave S, Abraham S, Ramkisson R, Tavormina G, Kolsanov A, Chaplygin S, Kozina T. Virtual Reality-Based Interventions for Treating Depression in the Context of COVID-19 Pandemic: Inducing the Proficit in Positive Emotions as a Key Concept of Recovery and a Path Back to Normality. Psychiatria danubina. 2022 Sep 1;34(Suppl 8):276-84.

19. Colombo D, Suso-Ribera C, Ortigosa-Beltrán I, Fernández-Álvarez J, García-Palacios A, Botella C. Behavioral Activation through Virtual Reality for Depression: A Single Case Experimental Design with

Multiple Baselines. J Clin Med. 2022 Feb 25;11(5):1262. doi: 10.3390/jcm11051262. PMID: 35268353; PMCID: PMC8911126

20. Valiengo L, Casati R, Bolognini N, Lotufo PA, Benseñor IM, Goulart AC, et al. Transcranial Direct Current Stimulation for the treatment of post-stroke depression in aphasic patients: a case series. Neurocase. 2016 Mar 3;22(2):225–8

21. Kiper P, Przysiężna E, Cieślik B, Broniec-Siekaniec K, Kucińska A, Szczygieł J, Turek K, Gajda R, Szczepańska-Gieracha J. Effects of Immersive Virtual Therapy as a Method Supporting Recovery of Depressive Symptoms in Post-Stroke Rehabilitation: Randomized Controlled Trial. Clin Interv Aging. 2022 Nov 23;17:1673-1685. doi: 10.2147/CIA.S375754. PMID: 36447623; PMCID: PMC9701456.
22. Falconer CJ, Rovira A, King JA, Gilbert P, Antley A, Fearon P, Ralph N, Slater M, Brewin CR. Embodying self-compassion within virtual reality and its effects on patients with depression. BJPsych Open. 2016 Feb 15;2(1):74-80. doi: 10.1192/bjpo.bp.115.002147. PMID: 27703757; PMCID: PMC4995586.
23. Rogers JM, Duckworth J, Middleton S, Steenbergen B, Wilson PH. Elements virtual rehabilitation improves motor, cognitive, and functional outcomes in adult stroke: evidence from a randomized controlled pilot study. J Neuroeng Rehabil. 2019 May 15;16(1):56. doi: 10.1186/s12984-019-0531-y. PMID: 31092252; PMCID: PMC6518680.
24. Modrego-Alarcón M, López-Del-Hoyo Y, García-Campayo J, Pérez-Aranda A, Navarro-Gil M, Beltrán-Ruiz M, Morillo H, Delgado-Suarez I, Oliván-Arévalo R, Montero-Marin J. Efficacy of a mindfulness-based programme with and without virtual reality support to reduce stress in university students: A randomized controlled trial. Behav Res Ther. 2021 Jul;142:103866. doi: 10.1016/j.brat.2021.103866. Epub 2021 Apr 26. PMID: 33957506.
25. Kothgassner OD, Goreis A, Kafka JX, Van Eickels RL, Plener PL, Felnhofer A. Virtual reality exposure therapy for posttraumatic stress disorder (PTSD): a meta-analysis. Eur J Psychotraumatol. 2019 Aug 19;10(1):1654782. doi: 10.1080/20008198.2019.1654782. PMID: 31489138; PMCID: PMC6713125.
26. Rowland DP, Casey LM, Ganapathy A, Cassimatis M, Clough BA. A Decade in Review: A Systematic Review of Virtual Reality Interventions for Emotional Disorders. Psychosoc Interv. 2022 Jan 1;31(1):1-20. doi: 10.5093/pi2021a8. PMID: 37362616; PMCID: PMC10268557.
27. Deng W, Hu D, Xu S, Liu X, Zhao J, Chen Q, Liu J, Zhang Z, Jiang W, Ma L, Hong X. The efficacy of virtual reality exposure therapy for PTSD symptoms: A systematic review and meta-analysis. Journal of affective disorders. 2019 Oct 1;257:698-709.
28. Li Y, Li HP, Wu MX, Wang QY, Zeng X. Effects of Transcranial Direct Current Stimulation for post-stroke depression: a systematic review and meta-analysis. Clinical Neurophysiology. 2022 Oct 1;142:1-0
29. Hummel F, Celnik P, Giraux P, Floel A, Wu WH, Gerloff C, Cohen LG. Effects of non-invasive cortical stimulation on skilled motor function in chronic stroke. Brain. 2005 Mar;128(Pt 3):490-9. doi: 10.1093/brain/awh369. Epub 2005 Jan 5. PMID: 15634731.
30. Lindenberg R, Renga V, Zhu LL, Nair D, Schlaug G. Bi-hemispheric brain stimulation facilitates motor recovery in chronic stroke patients. *Neurology*. 2010;75(24):2176-2184.
31. Bolognini N, Pascual-Leone A, Fregni F. Using non-invasive brain stimulation to augment motor training-induced plasticity. *J Neuroeng Rehabil*. 2009;6:8.