Development and Implementation of a Neurocognitive Training Program Incorporating Transcranial Direct Current Stimulation (tDCS)

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Abstract

Background: Maintaining cognitive functioning and performance remains a concern for aging adults. Cognitive performance is linked to quality of life outcomes. Limited knowledge exists of the effects of conducting neurocognitive training and incorporating tDCS.

Objective: The aim of this study is to examine the impact of a neurocognitive training program combined with transcranial direct current stimulation therapy on cognitive and memory performance of rehabilitative adults aged between 31 and 50 years of age.

Literature Review: Studies have shown that neurocognitive training combined with tDCS has been utilized in different patient groups, including healthy and ill patients. Some evidence suggests positive and moderate improvements in memory and cognitive performance in patients through neurocognitive training and tDCS. However, there is a need for more evidence from further research studies.

Methods: The practice change project will utilize an experimental pre-post design. Participants will be recruited through consecutive sampling. Participants will be assigned to either intervention or control group. Data collection will be performed pre- and post-intervention, before and after completion of the study. T-tests and linear regression statistical tests will be used for data analysis to test changes in outcome measures.

Conclusion: The proposed project entails developing and implementing a neurocognitive program among healthy adults utilizing tDCS. The study will contribute to the knowledge base that can be used in non-pharmacotherapy to improve cognitive functioning among rehabilitation individuals.

Keywords: *Cognitive function, neurocognitive training, transcranial direct current stimulation*

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Neurocognitive training programs have been utilized as a useful activities for stimulating the brain through active engagement in activities that seek to challenge the brain. The human brain is considered highly flexible and adaptable to novel experiences, making it more susceptible to neurocognitive training (Jolles & Crone, 2018). Previous studies have suggested that the brain structure, including the hippocampus, which is essential for memory as well as the brain's function, can be influenced by training (Jolles & Crone, 2018). For instance, studies have demonstrated alteration of activation of the brain in the limbic and frontoparietal regions after training involving memory activities and after meditation practices (Jolles & Crone, 2018). Cognitive training has led to improvements in cognitive self-efficacy among healthy older adults (Goghari & Lawlor-Savage, 2018). According to Cuevas et al. (2019), delivering cognitive training that utilizes available and acceptable measures is an innovative way to improve healthy lifestyle practices and outcomes. In addition, current cognitive training programs are developed and implemented in person in clinics (Cuevas et al., 2019). This paper proposes how to develop and implement a cognitive training program utilizing transcranial direct current stimulation (tDCS) and examine the associated effects.

Background

Maintenance of cognitive functioning and performance remains an important concern among many aging adults (Goghari & Lawlor-Savage, 2018). This is particularly true given the association of cognitive performance and quality of life among individuals (Goghari & Lawlor-Savage, 2018). Neurocognitive training is a common therapeutic intervention that leverages the brain's ability to establish new thoughts and behaviors. However, establishing new behaviors can be challenging and requires evidence-based approaches to guide neurocognitive training among subjects. There is also growing interest regarding the exploration of the benefits of non-pharmacological interventions such as modification of lifestyles, cognitive training, and repeated non-invasive stimulation of the brain (Das et al., 2019). Transcranial direct current stimulation is one such approach commonly utilized. Neurocognitive training approaches that target high-level cognitive functions such as reasoning are associated with many cognitive benefits (Das et al., 2019). However, the benefits of neurocognitive training combined with tDCS remain an area warranting further inquiry. Literature suggests that tDCS is implemented on the assumption of modulating synaptic plasticity and neuronal excitation capacity (Ke et al., 2019).

Transcranial direct current stimulation entails a non-invasive stimulation of the brain. It primarily focuses on attuning the cortical functioning through a weak of direct current (DC) applied to an individual's scalp (Das et al., 2019). In this procedure, the weak electrical current is provided through two electrodes, an anode and a cathode, that are placed on the scalp (Westwood et al., 2021). This produces sub-threshold shifts on resting membrane potentials of the brain regions (Westwood et al., 2021). The shifts in DC excitation are associated with modulating the neuronal networks. The neuropsychological effects are understood to persist after the tDCS, potentially by influencing synaptic plasticity mediators such as dopamine, glutamate, GABA, and noradrenaline (Westwood et al., 2021). However, evidence of the clinical improvement or cognitive performance after the tDCS therapy remains limited (Westwood et al., 2021). For this project, the goal is to understand the benefits of neurocognitive training augmented with tDCS in neurocognitive rehabilitation.

Importance of the Study

This study will contribute to increased knowledge and insights regarding the benefits of neurocognitive training incorporating tDCS. There is increased interest in understanding the impact of non-pharmacologic treatments to enhance cognition and function of adults without major neurocognitive functional needs (Fan & Wong, 2019). There is also minimal knowledge on the clinical benefits and cognitive outcomes for practitioners who use tDCS to modulate neurocognitive functioning and improve outcomes. Important to practice is the development of knowledge for health and promotion of health of individuals across the lifespan, as well as care for persons with health problems. The knowledge gained from this study will be useful in non-pharmacotherapy to help inform neurocognitive rehabilitation practice actions to enable individuals to manage potential and actual health problems. The study will help illuminate whether tDCS therapy can be augmented with neurocognitive training to improve cognition and performance in neurocognitive rehabilitation settings.

This study makes a tremendous contribution to developing a knowledge base in clinical practice. This particularly relates to the benefits of neurocognitive training and tDCS. Neurocognitive rehabilitation practitioners dealing with patients with impaired cognitive functioning or those utilizing non-pharmacological interventions will be able to utilize this knowledge for clinical decision-making. Understandably, by understanding the impacts or benefits of neurocognitive training incorporating tDCS, this study will contribute to evidence-based practice crucial to optimizing care for patients. It is important to recognize that cognitive training can be utilized for different patient demographics, including adolescents and healthy adult populations to improve their cognitive functions. Knowledge gained from this research can also be applied across patient populations and health settings to inform care offered to patients. Furthermore, this study may also impact the development of policies or protocols related to the use of tDCS in rehabilitative practice as well as the development and implementation of neurocognitive training programs.

Research Question

The PICOT question to guide this study will be: among healthy adults aged 31-50 years (P), what is the effect of a neurocognitive training program using transcranial direct current stimulation (tDCS) (I) compared to cognitive training alone (C) on cognitive and memory working performance measures (O) in eight weeks (T)? The study's aim entails examining whether a neurocognitive training program using transcranial direct current stimulation therapy can lead to improvements in cognitive and memory performance of individuals aged between 31 and 50 years. It is hypothesized that after the program, the cognitive performance and memory working measures will increase significantly. The study will also investigate the relationship between neurocognitive training combined with transcranial direct current stimulation therapy and age. The objectives of this study include implementing neurocognitive training activities and tasks, and augmenting them with transcranial direct current stimulation.

Literature Review

The use of transcranial direct current stimulation in supplementing neurocognitive training has been well established in the literature. Previous studies have examined the use of low doses of tDCS on influencing behavior, cognition, and performance. Meta-analyses of studies utilizing tDCS have found moderate improvement in control among children and teenagers with attention deficit hyperactivity disorder (ADHD) but no significant improvement on processing speed or attention (Salehinejad et al., 2019). Other studies have shown improvements in inattentive symptoms but no effect on hyperactivity/impulsivity (Westwood et al., 2021). Some evidence suggests that the effects of tDCS can be improved by combining it with cognitive training to prime regions responsible for mediating cognitive functions that are being trained (Westwood et al., 2021). A systematic review and meta-analysis study by Burton et al. (2023) provided preliminary evidence for the efficacy of combining tDCS and cognitive training on working memory or attention measures. Due to the small and non-significant outcomes, the authors suggested more studies to obtain more data and establish evidence in this area.

According to Zhu et al. (2022), cognitive training has shown improvement in cortical neuroplasticity. Bilateral tDCS of the prefrontal lobe along with computer-based cognitive training resulted in significant and positive changes in working memory performance (Zhu et al., 2022). This study revealed that when involving computer-based cognitive training, the tDCS-influenced bilateral changes due to prefrontal excitation may enhance cognitive decline (Zhu et al., 2022). These findings suggest the promising potential of using tDCS in neurocognitive training to improve an individual's working memory. Current evidence supports using multiple sessions of anodal tDCS along with cognitive training to provide longer-lasting cognitive performance and improvements in healthy subjects (Westwood et al., 2021).

A recent study conducted in 2019 also demonstrated that using bilateral tDCS to the frontal lobes, F3 and F4, and pairing it with cognitive training for two weeks improved functional connectivity and performance of working memory in healthy elderly adults (Nissim et al., 2019). In another study involving healthy adults, participants received both working memory cognitive training and tDCS. Participants received either sham or active anodal and high-definition tDCS, which was used for simulation of the left dorsolateral prefrontal cortex (Ke et al., 2019). The findings revealed higher learning rates in the active tDCS compared to sham stimulation (Ke et al., 2019). Similarly, performance improvements pre-post intervention were also higher than in the sham group (Ke et al., 2019). These findings further suggest the potential of leveraging tDCS to facilitate neurocognitive training for persons requiring improvements in working memory and cognition.

Methodology

This study focuses on implementing a neurocognitive training program utilizing tDCS in rehabilitation. Cognitive rehabilitation entails focusing on cognitive functions and behaviors necessary for achieving the highest levels of functioning and patient independence. After a brain injury, practitioners may use neurocognitive training to restore a patient's cognitive function. Typical examples of neurocognitive training programs may include eye movement, coordination of eyes and hands, crossword puzzles, and computer-based memory games. The aim is to keep the brain active, improve memory, and enhance cognitive functioning (Zhu et al., 2022).

Design

This study will use an experimental pretest and posttest design. This design is an experimental research where the effect or the outcome of the intervention is measured by comparing scores before and after implementing the intervention. The advantage of this research is directionality, where outcomes can be compared over time. In this case, the proposed plan is to have two groups, where one group is exposed to the intervention while the other is a control group. The participants will be randomly allocated into the intervention group, which will include neurocognitive training and transcranial direct current stimulation. The control will receive neurocognitive training alone.

Intervention

For the intervention group, tDCS will be provided bilaterally. The DCS can be delivered using a battery-powered simulator connected to electrode pairs. Active/sham stimulation will be applied over bilateral sensorimotor areas. The Cathode will be centered over C4 while the anode will be on the C3 scalp position in accordance with 10/20 international standards for electroencephalography (EEG) systems (Pellegrino et al., 2018). The model has been used previously in clinical applications. The intensity of DC current, its duration, and electrode size are important stimulation parameters that must be considered. Many behavioral studies have utilized 1 to 2mA, an electrode area of 25 cm^2, and 5 to 30 minutes of stimulation duration, which is considered human-safe (Herrera-Melendez et al., 2020).

For active simulation, the simulation may last 20 minutes with a 2mA current and 20-second fade-in/out (Pellegrino et al., 2018). For sham simulation, a similar setting is employed, but the current is only applied for 20 seconds at the start and end of stimulation. This aims to deliver a tingling sensation, which is reported by many subjects during real/active tDCS (Pellegrino et al., 2018). In addition, multiple sessions are associated with increased efficacy and sustainability of tDCS; thus, the proposed number of sessions is 25, as in many clinical trials (Herrera-Melendez et al., 2020). Neurocognitive training activities may include computer-based memory working activities such as memory games, crosswords, video games, and other new skills.

Sample

The target population for this study will include normal subjects aged between 31 and 50 years. For this project, the plan is to have two groups: 31-40 years and 41-50 years. For each group, subjects will be randomly assigned to either the intervention group or the control arm using a computerized number generator. This means a total of four subgroups will be obtained. Each subgroup will have about 15 subjects, implying a final sample size of 60 participants. This size will be considered big enough for collecting meaningful data and appropriate for project implementation. Participants will be recruited through a flyer placed in the facility. The flyer will contain details and reasons for the project, requirements for participation, and details of the project investigator (PI).

Consecutive sampling will be used to recruit participants. This is a non-probability recruitment approach where all eligible subjects that meet the inclusion criteria are recruited until reaching the sampling size required (Thewes et al., 2018). This helps to control sampling bias by including all available subjects (Thewes et al., 2018). The inclusion criteria will include adults aged 31-50 years, being free of any health conditions, including neurological conditions, and having the ability to use a computer. Individuals with any illness will be excluded to avoid the risk of contamination.

Ethical Considerations

The study will be conducted in accordance with the Institutional Review Board (IRB) recommendations. Thus, IRB approval will be obtained for this study. It is important that all individuals are free from any medical conditions. In addition, informed consent will be obtained from all prospective participants before they are included in the study, consistent with the Helsinki Declaration. Participants will be informed that their participation is voluntary and that they can exit the study at any time without needing to provide reasons for doing so. The participants will also be given adequate time to consider their participation to avoid any undue influence or coercion.

Data Collection

For all included participants, data collection will be conducted at baseline, two days before the study, and two days after completing the study. Pretest and posttest surveys will be distributed to all participants in person. Demographic information that will be collected will be age, gender, and educational level. Outcome measures will be collected using the cognitive functioning self-assessment scale (CFSS) and the memory working questionnaire. The CFSS is a validated self-assessment questionnaire for cognitive function (Ching et al., 2023). On the other hand, the WMQ is also self-administered and measures working memory dimensions, including short-term memory, executive control, and attention.

Analysis

Outcomes will be compared between groups and pre-post intervention. Descriptive statistics will be used to describe the data set. Inferential statistics will include t-tests and linear regression. Particularly, a paired-sampled t-test will be used to test differences in means between pretest and post-test groups while independent t-tests will be used to test changes between the intervention and control group. The statistical significance threshold, p-value <0.05 will be considered statistically significant. Linear regression analyses will be used to compare changes between demographics and outcomes. For regression analyses, Pearson correlation coefficient (R), determination coefficient, and significance value (p) will be reported. All statistical tests will be run on IMB SPSS v25.

Conclusion

The proposed project entails developing and implementing a neurocognitive program among healthy adults utilizing tDCS. Previous studies have suggested benefits of combining cognitive training along with tDCS to improve cognitive and memory working outcomes. The project will be conducted in eight weeks and pretest and posttest measures will be used for data collection and evaluation of outcomes. This study is important in contributing to knowledge base that can be used in non-pharmacotherapy to improve cognition functioning.

References

Burton, C. Z., Garnett, E. O., Capellari, E., Chang, S.-E., Tso, I. F., Hampstead, B. M., & Taylor, S. F. (2023). Combined cognitive training and transcranial direct current stimulation in neuropsychiatric disorders: A systematic review and meta-analysis. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *8*(2), 151–161. https://doi.org/10.1016/j.bpsc.2022.09.014

Ching, K., Nam, S., Li, S., Sze, H., Yuen, J., Yan, Y., Davies, H., Huang, L., Maria Antonietta Annunziata, & Yee, D. (2023). Psychometric properties of the cognitive functioning self-assessment scale in community-dwelling adults: A cross-sectional online survey. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1122198

Cuevas, H. E., Stuifbergen, A. K., Brown, S. A., & Ward, C. (2019). A nurse-led cognitive training intervention for individuals with type 2 diabetes. *Research in Gerontological Nursing*, *12*(4), 203–212. https://doi.org/10.3928/19404921-20190612-01

Das, N., Spence, J. S., Aslan, S., Vanneste, S., Mudar, R., Rackley, A., Quiceno, M., & Chapman, S. B. (2019). Cognitive training and transcranial direct current stimulation in mild cognitive impairment: A randomized pilot trial. *Frontiers in Neuroscience*, *13*. https://doi.org/10.3389/fnins.2019.00307

Fan, B. J. Y., & Wong, R. Y. M. (2019). Effect of cognitive training on daily function in older people without major neurocognitive disorder: A systematic review. *Geriatrics*, *4*(3), 44. https://doi.org/10.3390/geriatrics4030044

Goghari, V. M., & Lawlor-Savage, L. (2018). Self-perceived benefits of cognitive training in healthy older adults. *Frontiers in Aging Neuroscience*, *10*. https://doi.org/10.3389/fnagi.2018.00112

Herrera-Melendez, A.-L., Bajbouj, M., & Aust, S. (2020). Application of transcranial direct current stimulation in psychiatry. *Neuropsychobiology*, *79*(6), 372–383. https://doi.org/10.1159/000501227

Jolles, D. D., & Crone, E. A. (2018). Training the developing brain: A neurocognitive perspective. *Frontiers in Human Neuroscience*, *6*. https://doi.org/10.3389/fnhum.2018.00076

Ke, Y., Wang, N., Du, J., Kong, L., Liu, S., Xu, M., An, X., & Ming, D. (2019). The effects of transcranial direct current stimulation (tDCS) on working memory training in healthy young adults. *Frontiers in Human Neuroscience*, *13*. https://doi.org/10.3389/fnhum.2019.00019

Nissim, N. R., O'Shea, A., Indahlastari, A., Kraft, J. N., von Mering, O., Aksu, S., Porges, E., Cohen, R., & Woods, A. J. (2019). Effects of transcranial direct current stimulation paired with cognitive training on functional connectivity of the working memory network in older adults. *Frontiers in Aging Neuroscience*, *11*. https://doi.org/10.3389/fnagi.2019.00340

Pellegrino, G., Maran, M., Turco, C., Weis, L., Di Pino, G., Piccione, F., & Arcara, G. (2018). Bilateral transcranial direct current stimulation reshapes resting-state brain networks: A magnetoencephalography assessment. *Neural Plasticity*, *2018*, 1–10. https://doi.org/10.1155/2018/2782804

Salehinejad, M. A., Wischnewski, M., Nejati, V., Vicario, C. M., & Nitsche, M. A. (2019). Transcranial direct current stimulation in attention-deficit hyperactivity disorder: A meta-analysis of neuropsychological deficits. *PLOS ONE*, *14*(8), e0221613. https://doi.org/10.1371/journal.pone.0221613

Thewes, B., Rietjens, J. A. C., van den Berg, S. W., Compen, F. R., Abrahams, H., Poort, H., van de Wal, M., Schellekens, M. P. J., Peters, M. E. W. J., Speckens, A. E. M., Knoop, H., & Prins, J. B. (2018). One way or another: The opportunities and pitfalls of self-referral and consecutive sampling as recruitment strategies for psycho-oncology intervention trials. *Psycho-Oncology*, *27*(8), 2056–2059. https://doi.org/10.1002/pon.4780

Westwood, S. J., Criaud, M., Lam, S.-L., Lukito, S., Wallace-Hanlon, S., Kowalczyk, O. S., Kostara, A., Mathew, J., Agbedjro, D., Wexler, B. E., Cohen Kadosh, R., Asherson, P., & Rubia, K. (2021). Transcranial direct current stimulation (tDCS) combined with cognitive training in adolescent boys with ADHD: a double-blind, randomized, sham-controlled trial. *Psychological Medicine*, *53*(2), 1–16. https://doi.org/10.1017/s0033291721001859

Zhu, X., Huang, C., Fan, H., Fan, F., Zhao, Y., Xiu, M., Wang, Y., Li, Y., Tan, Y., Wang, Z., & Tan, S. (2022). The effect of transcranial direct current stimulation combined with working memory training on working memory deficits in schizophrenic patients: Study protocol for a randomized controlled trial. *Trials*, *23*, 826. https://doi.org/10.1186/s13063-022-06776-x