Journal of
Research in Psychopathology
https://dx.doi.org/10.22098/jrp.2020.1029

2020, Vol. 1, No. 1

Original Article

Comparing the effects of transcranial direct-current stimulation (tDCS) and mindfulness based cognitive therapy (MBCT) on forward and backward memory span in patients with epilepsy

Shahin Azmoodeh[1], Esmaeil Soleimani[2*] and Ali Issazadegan[3]

1. Ph.D. in Psychology, Department of Psychology, Faculty of Literature and Humanities, Urmia University, Urmia, Iran
2. Associate Professor, Department of Psychology, Faculty of Literature and Humanities, Urmia University, Urmia, Iran
3. Professor, Department of Psychology, Faculty of Literature and Humanities, Urmia University, Urmia, Iran

Abstract

The present study aimed to compare the effects of tDCS and MBCT on forward and backward memory span in patients with epilepsy. The sample consisted of 45 patients with epilepsy who were selected by convenience sampling and assigned to two experimental and one control groups. In data collection phase, a pretest was administered using Wechsler Scale, tDCS and MBCT interventions were applied, and then posttest was performed. The findings from MANCOVA analyses showed that there were significant differences between experimental and control groups. Both experimental groups demonstrated significant improvements in posttest in terms of the components of working memory. The results showed that tDCS and MBCT can enhance working memory in patients with epilepsy; however, the effect of tDCS was more significant.

Keywords

Backward memory span
Epilepsy
Forward memory span
MBCT
tDCS

Received: 2020/03/12
Accepted: 2020/05/23
Available Online: 2020/06/30

Introduction

Epilepsy is a neurological disorder that involves central nervous system, and more than fifty million people in the world are affected by this disease. There are several reports on the prevalence of this disorder. World Health Organization acknowledged that its prevalence in general population is about 4-10 per 1000 persons (World Health Organization, 2016). Recently, Fiest et al., (2017) declared the lifetime prevalence of Epilepsy as 7.6 per 1,000 persons. Despite the fact that seizure is the most prominent symptom of epilepsy, the problems of the affected patients are far beyond this. In addition to epileptic seizures, somatic, psychological, and cognitive disorders greatly affect the lives of these patients. Epilepsy comorbidities include anxiety disorders, depression, stress, sleep disturbances, migraines, and problems in executive functions (Holmes, 2015). Memory dysfunction is more or less observed in people with various neurological and psychological disorders. Among cognitive problems, memory deficits are considered as the most frequent disabilities in patients with epilepsy (Zeman, Kapur, & Jones-Gotman, 2012). Fisher et al., (2000) surveyed 1000 patients with epilepsy and concluded that cognitive problems are at the forefront. In another study, the researchers showed that 54% of the patients with epilepsy suffered from memory problems (Thompson & Corcoran, 1992). Cognitive disabilities in epilepsy are multifactorial. Some of the important factors include side effects of antiepileptic drugs and patient-related variables (Mula, 2015). Ancient Greek philosophers such as Aristotle considered the memory merely as a functional instrument. However, subsequent studies on memory defects highlighted its importance, since it acts as storage to preserve the past which represents our identity or who we are (Zeman et al., 2012). Memory impairment negatively influences the quality of life (Fisher et al., 2000). In addition, Sherman, Slick, & Eyrl, (2006) showed that executive dysfunction causes a poor quality of life in patients. Due to the problems that memory deficit causes in the patients' life, some interventions are necessary to enhance memory's

Corresponding author: Esmaeil Soleimani, Department of Psychology, Urmia University, Urmia, Iran.
Email: soleymany.psy@gmail.com

effectiveness. In the present research, among different interventions, transcranial direct-current stimulation (tDCS) and mindfulness-based cognitive therapy (MBCT) was selected.

Nowadays, tDCS is one of the most practical and non-invasive ways which has been used in therapy since 1998 (Sarmiento, San-Juan, & Prasath, 2016). It should be noted that there is an increasing interest in tDCS among the scientific community. The basic feature of tDCS is the application of a weak electric current that stimulates the target area of cerebral cortex via two electrodes (Rogers, 2016). Carvalho et al., (2015), and Rohan, Carhuatanta, McInturf, Miklasevich, & Jankord, (2015) demonstrated that tDCS is useful in learning, cognition, and memory enhancement. Mulquiney, Hoy, Daskalakis, & Fitzgerald, (2011) used tDCS to improve working memory (WM). Their target region was DLPFC, and the results showed that enhancing WM through tDCS is possible. Temporal lobe epilepsy often accompanies memory impairment. Del Felice, Magalini, & Masiero, (2015) used Oscillatory Transcranial Direct Current Stimulation (OtDCS) in case of 12 patients with temporal lobe epilepsy for 30 minutes. The results showed that anodal stimulation improved visual-spatial and declarative memory. Bystad et al., (2016) used tDCS as a memory enhancer in patients with Alzheimer's disease. The researchers used 2 mA for 30 minutes in 6 sessions, and the results depicted that the tDCS group showed a significant improvement in memory compared to that of the control group. Another effective intervention is MBCT which is an approach in psychological therapy that combines mindfulness technique with cognitive behavioral therapy methods (Seligman & Lourie, 2014). Mindfulness involves mind and body and promotes the well-being of participants. The most prominent feature of this method is its non-judgmental, focusing, and attaching importance in presenting the moment (Berk, Warmenhoven, van Os, & van Boxtel, 2018). Several studies have been conducted on the efficacy of MBCT in improving memory loss. For instance, Jha, Stanley, Kiyonaga, Wong, & Gelfand, (2010), examined the effects of the mindfulness training on WM. The results showed the usefulness of this method in cognitive function (Manna et al., 2010). Besides, Teasdale et al., (2000), acknowledged that mindfulness training can enhance the capacity of WM. Similarly, Bloom, (2011) in a case study surveyed the effects of MBCT on WM and showed the clinical significance and reliable changes in WM. According to literature, memory dysfunction has not been comprehensively surveyed using these two methods in patients with epilepsy. Thus, in the present study, we aimed to compare the effects of tDCS and MBCT on forward and backward memory span in these patients.

Method

Participants

The present study adhered to a quasi-experimental design and used pretests, posttests, and control groups. The population consisted of all patients with epilepsy who were referred to private clinics in Urmia. The sample consisted of 45 patients with epilepsy who were selected by convenience sampling and assigned to two experimental and one control groups

Instrument

Working Memory Tasks

Wechsler Numerical Memory Scale is a short-term memory test. The subjects must remember and repeat the audio information in an appropriate order. In this scale, correct answers require a two-stage process. First, information must be carefully obtained, which requires attention and encoding. Those who are easily distracted may have difficulty at this stage. In the second stage, the subjects must correctly remember the information and express them in a correct sequence. Those who do not correctly receive the information may have difficulty at this stage (Pasha Sharifi & Nikkhooi, 2003). In this scale, the lists of 3 to 9 digits are presented verbally, and the participant must recall them. In the second part, the participant must recall lists of 2 to 8 digits reversely (Anastasi & Baraheni, 1992). Although recalling forward digits are easier and requires parrot-like memory, recalling the backward digits are more complex, and participant must usually hold the information for a longer time in the memory and, must change the order before the recall. Hence high performance in backward digits may reflect the ability of the person who has a high level of flexibility, focus, and stress tolerance. Besides, the high score in repeating the backward digits may be related to the ability of forming visual mental images as well as maintaining and scanning them when needed. It is clear that those who are passive and anxiety-free get the best score in this test. Increasing anxiety or stress causes a decrease in performance. Test-retest reliabilities for all age groups over an interval were approximately about 2 to 12 weeks, ranged between .62 and .82 for the individual subtests and between .75 and .88 for the indexes. The Wechsler Memory Scale III (WAIS-III) and Wechsler Adult Intelligence Scale III (WMS-III) guidelines indicate that the internal consistency of the primary subtest scores varies between .74 and .93 (Pasha Sharifi & Nikkhooi, 2003). In the present study, the Cronbach's alpha coefficient was found to be .801.

Procedure

To gather the data, first, a pretest was administered using Wechsler Scale. Next, tDCS and MBCT interventions were implemented, and then post-test was performed. The tDCS was applied for 20 min over the left DLPFC, the intensity of which was 1.5 mA. This method was applied in the first experimental group for 10 sessions. The first 5 sessions were consecutive, and the next 5 sessions were held every other day. Based on the International 10–20 system, the anodal electrode was placed in the F3 region of the left hemisphere, and the cathodal electrode was placed in the F4 region of the right hemisphere. The MBCT intervention constituted an eight-week program that was implemented in the second experimental group. The class time included 2-2.5 h weekly. Participants were encouraged to complete daily home practice for 6 days per week. The duration of home sessions was about 45 min

Results

In the first step, the data was analyzed using descriptive statistics. The results presented in the Table 1 illustrate the mean and standard deviation (SD) of Forward and Backward Memory Span in pretest and post- test in control and experimental groups.

Table 1. Descriptive indicators of working memory in experimental and control groups

	Variables	tDCS		MBCT		Control	
		M	SD	M	SD	M	SD
Pretest	Forward Memory Span	8.1333	1.06010	8.2667	1.1629	7.6000	1.12122
	Backward Memory Span	5.8000	.94112	6.8000	1.5212	5.6667	.97590
Posttest	Forward Memory Span	11.690	.218	10.412	.231	8.099	.225
	Backward Memory Span	8.874	.208	6.861	.220	6.199	.215

To ensure the homogeneity of variance, Levene's test and Box's M test were used. The results of the Levene's test for the equality of variance showed that both of the components including forward memory span (F (2, 42) =1.778, P=.181) and backward memory span (F (2, 42) =.033, P=.968) in control and experimental groups were equal. Additionally, the Box's M test (F (43964, 6) =.782, P=.584) showed a good level of homogeneity.

The results of Table 2 show that multivariate covariance analysis can be used due to the significance values of the tests (MANOVA) ($p < 0.001$). Besides, it is clear that the experimental and control groups are significantly different at least in terms of one dependent variable. According to Wilks' Lambda test, the difference is 14%. It means that 14% of the variance among the three groups is related to the interaction of dependent variables.

Table 2. Comparing the experimental and control groups using MANCOVA in working memory

Source		**Value**	**F**	**Hypothesis df**	**Error df**	**P**	**Eta**
Group	Pillai's Trace	1.056	22.386	4.000	80.000	.000	.528
	Wilks' Lambda	.148	31.239[a]	4.000	78.000	.000	.616
	Hotelling's Trace	4.389	41.698	4.000	76.000	.000	.687
	Roy's Largest Root	4.048	80.963[b]	2.000	40.000	.000	.802

The result of multivariate analysis of covariance is presented in Table 3. As indicated, there is significant differences among the three groups with regard to the scores of forward (F=67.479) and backward (F=44.691) memory span in the post – test ($P < 0.000$).

Table 3. MANCOVA on mean values of the components of working memory

Source	Dependent variables	SS	df	MS	F	P	Eta
Memory	Forward Memory Span	93.782	2	46.891	67.479	.000	.771
	Backward Memory Span	56.680	2	28.340	44.691	.000	.691

The results of post hoc tests for paired comparisons through Bonferroni correction are presented in Table 4. According to the table, there is a statistically significant difference between the means of tDCS and control groups in terms of the components of WM. In addition, the results of Table 1 indicate that tDCS is effective in improving WM. It should be noted that MBCT and control groups are significantly different with regard to the components of WM. According to the results of Table 1, MBCT is effective in upgrading WM. Furthermore, the differences between tDCS and MBCT groups are significant. As Table 1 depicts, tDCS Method is more effective.

Table 4. Bonferroni's multiple comparisons test

Dependent variable	Groups	Mean Weight Difference tDCS	MBCT	Control
Forward Memory Span	tDCS	-	1.278*	3.591*
	MBCT	-1.278*	-	2.313*
Backward Memory Span	tDCS	-	2.013*	2.675*
	MBCT	-2.013*	-	.662*

* Correlation is significant at the 0.05 level (2-tailed).

Discussion

The present study aimed to investigate and compare the effects of tDCS and MBCT on forward and backward memory span in patients with epilepsy. The findings showed that there were significant differences between two experimental and control groups in terms of WM components. Besides, the results of Bonferroni test showed that there was a significant difference between tDCS and control groups in terms of WM. According to the Tables above, tDCS is effective in enhancing WM in patients. This finding is consistent with studies of Ruf, Fallgatter, & Plewnia, (2017), Trumbo et al., (2016), Bystad et al., (2016), Del Felice et al., (2015), Liu et al., (2014), and Jo et al., (2009). In the present study, tDCS was used for stimulating the DLPFC region. Executive functions, as complex mental activities, are related to this area of the brain (Elliott, 2003). The tDCS, as a neuromodulatory technique, has shown acceptable performance in enhancing neurocognitive activity and treating neuropsychiatric disorders (Giordano et al., 2017). The current used in tDCS affects the neurons and makes changes in the intensity of the neuronal firing of the cells (Cambiaghi et al., (2010). The studies on the biological effects of tDCS showed that it can affect the level of glutamate (GLU), gamma-amino butyric acid (GABA), and glutamine (Dwyer et al., 2019). It is believed that glutamate (GLU) and gamma-amino butyric acid (GABA) play important roles in memory and other brain functions (Tabassum et al., 2017); however, none of these amino acids can introduce cognitive problems alone. Therefore, GLU/GABA balance is very useful in understanding the mechanism of cognitive deficits (Krause, Márquez-Ruiz, & Cohen Kadosh, 2013). It should be noted that the contribution of these amino acids is necessary for prefrontal cognitive activity among healthy individuals (Jocham, Hunt, Near, & Behrens, 2012). In some disorders, the level of GLU/GABA changes in ADHD and GLU has increased (Arcos-Burgos et al., 2012), and GABA level has decreased (Edden, Crocetti, Zhu, Gilbert, & Mostofsky, 2012). According to the provided content, in memory problems, the imbalance of GLU/GABA may occur which can be balanced by tDCS. On the other hand, Weiss & Lavidor, (2012) demonstrated that cathodal stimulation of prefrontal cortex filters the irrelevant information. It is evident that focusing on main information and neglecting the irrelevant ones look essential to obtain an acceptable performance of WM.

Another part of the present study was related to MBCT group. As it is clear in Table 4, Bonferroni test showed that there were significant differences between MBCT and control groups with regard to WM. According to the presented Tables, MBCT is effective for enhancing memory in patients with epilepsy. This finding is consistent with studies of Lao, Kissane, & Meadows, (2016), Tang, Hölzel, & Posner, (2015), and Tang, Poon, & Kwan, (2015), Chiesa, Calati, & Serretti, (2011), Bloom, (2011). In order to interpret the above-mentioned findings, it is essential to notice the function of mindfulness and the mechanism of WM. One of the most prominent features of meditation is its potential in reducing or eliminating the irrelevant thoughts and focusing full attention on the intended information (Rubia, 2009). This feature is an important factor in optimal WM performance. Segal et al. (2002) acknowledged that in MBCT, participants are encouraged to notice the present moment and should not evaluate the experiences. Focusing and cognitive monitoring are the most common features in MBCT and executive functions (Austin et al., 1999). Besides, these common characteristics of the zone that MBCT affects and part of the memory it involves are the same. In other words, one of the important parts of the brain involved in memory is prefrontal cortex (PFC) that encodes the information in WM (Baddeley, 2003), and poor performance of this part causes deficits in executive function. As mentioned before, MBCT is a method that affects the PFC and can be effective in enhancing WM. The mechanism of MBCT's effect creates changes in the brain's structure and function in the long term (Gotink, Meijboom, Vernooij, Smits, & Hunink, 2016). Widdett, (2014) expressed that regular practicing of mindfulness can have strengthening and stabilizing effects on neurons of medial prefrontal cortex. In other words, meditation can cause neuroplasticity and create new synaptic connections between neurons. Thus, according to the provided content, MBCT's effects on WM are justifiable.

Conclusion

The results showed that tDCS and MBCT can enhance WM in patients with epilepsy; however, tDCS was a little more effective. In addition, the lower effectiveness of MBCT requires further research. In fact, the effectiveness of MBCT increases in accordance with practice and time continuity. In the present study, we used patients with epilepsy for gathering the data. This may cause some limitations in generalizing the findings. Therefore, future researchers are recommended to use different samples. The other problem is related to the limited time in the present study, since MBCT leads to more reliable results if continued

Conflict of interest

The authors of this article declare that there was no conflict of interest.

ORCID

Esmaeil Soleimani http:/ orcid. Org/ 0000+0002+7204+1229

References

Anastasi, A. (1992). Psychological testing. Baraheni MN. Tehran. Tehran University Press, 3rd ed (Persian translator). doi: 10.1002/j.1556-6676.1992.tb01670.

Arcos-Burgos, M., Londoño, A. C., Pineda, D. A., Lopera, F., Palacio, J. D., Arbelaez, A., Muenke, M. (2012). Analysis of brain metabolism by proton magnetic resonance spectroscopy (1 H-MRS) in attention-deficit/hyperactivity disorder suggests a generalized differential ontogenic pattern from controls. ADHD Attention Deficit and Hyperactivity Disorders, 4(4), 205–212. doi: 10.1007/s12402-012-0088-0

Austin, M.-P., Mitchell, P., Wilhelm, K., Parker, G., Hickie, I., Brodaty, H., Hadzi-Pavlovic, D. (1999). Cognitive function in depression: a distinct pattern of frontal impairment in melancholia? Psychological Medicine, 29(1), 73–85. doi: 10.1017/s0033291798007788.

Baddeley, A. (2003). Working memory: looking back and looking forward. Nature Reviews Neuroscience, 4(10), 829. doi: 10.1038/nrn1201.

Berk, L., Warmenhoven, F., van Os, J., & van Boxtel, M. (2018). Mindfulness training for people with dementia and their caregivers: rationale, current research, and future directions. Frontiers in Psychology, 9, 982. doi: 10.3389/fpsyg.2018.00982.

Bloom, A. R. Z. (2011). The effects of meditation on working memory and depression in an older adult: a case study. doi: 10.1111/nyas.12348

Bystad, M., Grønli, O., Rasmussen, I. D., Gundersen, N., Nordvang, L., Wang-Iversen, H., & Aslaksen, P. M. (2016). Transcranial direct current stimulation as a memory enhancer in patients with Alzheimer's disease: a randomized, placebo-controlled trial. Alzheimer's Research & Therapy, 8(1), 13. doi: 10.1186/s13195-016-0180-3.

Cambiaghi, M., Velikova, S., Gonzalez-Rosa, J. J., Cursi, M., Comi, G., & Leocani, L. (2010). Brain transcranial direct current stimulation modulates motor excitability in mice. European Journal of Neuroscience, 31(4), 704–709. doi: 10.1111/j.1460-9568.2010.07092.x.

Carvalho, S., Boggio, P. S., Gonçalves, Ó. F., Vigário, A. R., Faria, M., Silva, S., … Leite, J. (2015). Transcranial direct current stimulation based metaplasticity protocols in working memory. Brain Stimulation, 8(2), 289–294. doi: 10.1016/j.brs. 2014.11.011

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. Clinical Psychology Review, 31(3), 449–464. doi: 10.1016/j.cpr.2010.11.003.

Del Felice, A., Magalini, A., & Masiero, S. (2015). Slow-oscillatory transcranial direct current stimulation modulates memory in temporal lobe epilepsy by altering sleep spindle generators: a possible rehabilitation tool. Brain Stimulation, 8(3), 567–573. doi: 10.1016/j.brs.2015.01.410.

Dwyer, G. E., Craven, A. R., Hirnstein, M., Kompus, K., Assmus, J., Ersland, L., Grüner, R. (2019). No effects of anodal tDCS on local GABA and Glx levels in the left posterior superior temporal gyrus. Frontiers in Neurology, 9, 1145. doi: 10.3389/fneur.2018.01145

Edden, R. A. E., Crocetti, D., Zhu, H., Gilbert, D. L., & Mostofsky, S. H. (2012). Reduced GABA concentration in attention-deficit/hyperactivity disorder. Archives of General Psychiatry, 69(7), 750–753. doi: 10.1001/archgenpsychiatry.2011.2280.

Elliott, R. (2003). Executive functions and their disorders: Imaging in clinical neuroscience. British Medical Bulletin, 65(1), 49–59. doi: 10.1093/bmb/65.1.49

Fiest, K. M., Sauro, K. M., Wiebe, S., Patten, S. B., Kwon, C.-S., Dykeman, J., Jetté, N. (2017). Prevalence and incidence of epilepsy: a systematic review and meta-analysis of international studies. Neurology, 88(3), 296–303. doi: 10.1212/WNL.0000000000003509

Fisher, R. S., Vickrey, B. G., Gibson, P., Hermann, B., Penovich, P., Scherer, A., & Walker, S. (2000). The impact of epilepsy from the patient's perspective I. Descriptions and subjective perceptions. Epilepsy Research, 41(1), 39–51. doi: 10.1016/s0920-1211(00)00126-1

Giordano, J., Bikson, M., Kappenman, E. S., Clark, V. P., Coslett, H. B., Hamblin, M. R., McKinley, R. A. (2017). Mechanisms and effects of transcranial direct current stimulation. Dose-Response, 15(1), 1559325816685467. doi: 10.1177/1559325816685467

Gotink, R. A., Meijboom, R., Vernooij, M. W., Smits, M., & Hunink, M. G. M. (2016). 8-week mindfulness based stress reduction induces brain changes similar to traditional long-term meditation practice–a systematic review. Brain and Cognition, 108, 32–41. doi: 10.1016/j.bandc.2016.07.001

Holmes, G. L. (2015). Cognitive impairment in epilepsy: the role of network abnormalities. Epileptic Disorders, 17(2), 101–116. doi: 10.1684/epd.2015.0739.

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. Emotion, 10(1), 54. doi: 10.1037/a0018438.

Jo, J. M., Kim, Y.-H., Ko, M.-H., Ohn, S. H., Joen, B., & Lee, K. H. (2009). Enhancing the working memory of stroke patients using tDCS. American Journal of Physical Medicine & Rehabilitation, 88(5), 404–409. doi: 10.1097/PHM.0b013e3181a0e4cb.

Jocham, G., Hunt, L. T., Near, J., & Behrens, T. E. J. (2012). A mechanism for value-guided choice based on the excitation-inhibition balance in prefrontal cortex. Nature Neuroscience, 15(7), 960–961. doi: 10.1038/nn.3140

Krause, B., Márquez-Ruiz, J., & Cohen Kadosh, R. (2013). The effect of transcranial direct current stimulation: a role for cortical excitation/inhibition balance? Frontiers in Human Neuroscience, 7, 602. doi: 10.3389/fnhum.2013.00602.

Lao, S.-A., Kissane, D., & Meadows, G. (2016). Cognitive effects of MBSR/MBCT: A systematic review of neuropsychological outcomes. Consciousness and Cognition, 45, 109–123. doi: 10.1016/j.concog.2016.08.017.

Liu, A., Devinsky, O., Bryant, A., Jefferson, A., Friedman, D., Shafi, M., O'Connor, M. (2014). Efficacy of transcranial direct current stimulation on working memory and mood in patients with temporal lobe epilepsy (S43. 006). AAN Enterprises. doi: 10.1016/j.yebeh.2015.10.032.

Manna, A., Raffone, A., Perrucci, M. G., Nardo, D., Ferretti, A., Tartaro, A., Romani, G. L. (2010). Neural correlates of focused attention and cognitive monitoring in meditation. Brain Research Bulletin, 82(1–2), 46–56. doi: 10.1016/j.brainresbull.2010.03.001

Mula, M. (2015). Cognitive dysfunction in patients with epilepsy: focus on clinical variables. Future Neurology, 10(1), 41–48. doi: 10.2217/fnl.14.65.

Mulquiney, P. G., Hoy, K. E., Daskalakis, Z. J., & Fitzgerald, P. B. (2011). Improving working memory: exploring the effect of transcranial random noise stimulation and transcranial direct current stimulation on the dorsolateral prefrontal cortex. Clinical Neurophysiology, 122(12), 2384–2389. doi: 10.1016/j.clinph.2011.05.009.

Rohan, J. G., Carhuatanta, K. A., McInturf, S. M., Miklasevich, M. K., & Jankord, R. (2015). Modulating hippocampal plasticity with in vivo brain stimulation. Journal of Neuroscience, 35(37), 12824–12832. doi: 10.1523/JNEUROSCI.2376-15.2015

Rubia, K. (2009). The neurobiology of meditation and its clinical effectiveness in psychiatric disorders. Biological Psychology, 82(1), 1–11. doi: 10.1016/j.biopsycho.2009.04.003

Ruf, S. P., Fallgatter, A. J., & Plewnia, C. (2017). Augmentation of working memory training by transcranial direct current stimulation (tDCS). Scientific Reports, 7(1), 876. doi:10.1016/j.schres.2009.09.022

Sarmiento, C. I., San-Juan, D., & Prasath, V. B. S. (2016). Letter to the Editor: Brief history of transcranial direct current stimulation (tDCS): from electric fishes to microcontrollers. Psychological Medicine, 46(15), 3259–3261. doi: 10.1017/S0033291716001926.

Sherman, E. M. S., Slick, D. J., & Eyrl, K. L. (2006). Executive dysfunction is a significant predictor of poor quality of life in children with epilepsy. Epilepsia, 47(11), 1936–1942. doi: 10.1111/j.1528-1167.2006.00816.x

Tabassum, S., Ahmad, S., Madiha, S., Khaliq, S., Shahzad, S., Batool, Z., & Haider, S. (2017). Impact of oral supplementation of Glutamate and GABA on memory performance and neurochemical profile in hippocampus of rats. Pakistan Journal of Pharmaceutical Sciences, 30. PMID: 28655701

Tang, V., Poon, W. S., & Kwan, P. (2015). Mindfulness-based therapy for drug-resistant epilepsy: an assessor-blinded randomized trial. Neurology, 85(13), 1100–1107. doi: 10.1212/WNL.0000000000001967.

Tang, Y.-Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. Nature Reviews Neuroscience, 16(4), 213–225.doi: 10.1038/nrn3916

Teasdale, J. D., Segal, Z. V, Williams, J. M. G., Ridgeway, V. A., Soulsby, J. M., & Lau, M. A. (2000). Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. Journal of Consulting and Clinical Psychology, 68(4), 615. doi: 10.1037//0022-006X.68.4.615

Thompson, P. J., & Corcoran, R. (1992). Everyday memory failures in people with epilepsy. Epilepsia, 33, S18-20. PMID: 1486831.

Trumbo, M. C., Matzen, L. E., Coffman, B. A., Hunter, M. A., Jones, A. P., Robinson, C. S. H., & Clark, V. P. (2016). Enhanced working memory performance via transcranial direct current stimulation: The possibility of near and far transfer. Neuropsychologia, 93, 85–96. doi: 10.1016/j.neuropsychologia.2016.10.011.

Weiss, M., & Lavidor, M. (2012). When less is more: evidence for a facilitative cathodal tDCS effect in attentional abilities. Journal of Cognitive

Neuroscience, 24(9), 1826–1833. doi: 10.1162/jocn_a_00248.

Widdett, R. (2014). Neuroplasticity and mindfulness meditation. Honors Theses. 2469. https://scholarworks.wmich.edu/honors_theses/2469

Zeman, A., Kapur, N., & Jones-Gotman, M. (2012). Epilepsy and memory. Oxford University Press. doi:10.1093/acprof:oso/9780199580286.001.0001