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Narrative Review

Transcranial Direct Current Stimulation (TDCS).

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Abstract

Transcranial direct current stimulation (TDCS) is a neuromodulatory device that is used for its ability to enhance cognitive and behavioral performance. Human studies suggest that TDCS modulates cortical excitability during stimulation by nonsynaptic changes of the cells, along with evidence that the after-effects of TDCS are driven by synaptic modification. TDCS represents a potential intervention to enhance cognition across clinical populations, including mild cognitive impairment among psychological and neurological disorders. Studies suggest that TDCS might be helpful in treating depression with appropriate current, size of electrodes, and employment of montages. TDCS opens a new perspective in treating major depressive disorder (MDD) because of its ability to modulate cortical excitability and induce long-lasting effects.

Keywords

Transcranial Direct Current Stimulation, Neuromodulatory, Depression, Cognition.

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Introduction

Transcranial direct current stimulation (TDCS) is a neuromodulatory device used to enhance cognitive and behavioral performance[1]. TDCS method is a non-invasive brain stimulation with low electrical current using anode and cathode electrodes[2]. 1980 was a breakthrough for non-invasive electrical brain stimulation in humans by applying high voltage stimulus to the motor cortex for milliseconds. TDCS is fundamentally different from other transcranial electrical stimulations because it is a subthreshold stimulation, and one can see physiological effects here[3].

Physiological basis for TDCS

Studies have demonstrated the shreds of evidence for the physiological basis of TDCS that suggest that TDCS modulated synaptic strength within the motor cortex. Human studies indicate that TDCS modulates cortical excitability during stimulation by nonsynaptic changes of the cells, along with evidence that the after-effects of TDCS are driven by synaptic modification[4]. The electrode is commonly placed over the motor cortex for cortical motor stimulation, while the reference electrode is placed over the contralateral supraorbital ridge[4]. The threshold for induction of action potential in response to stimulation polarity modifies the resting membrane potential in hyperpolarizing direction, which means more incoming activity is needed to induce the action potential[3]. While depolarization is induced, less activity is needed to induce such a suprathreshold depolarization, which is triggered red by spontaneous neuronal activity by afferent activation of neurons[3]. For practical application, the go and flow direction in relation to neuronal orientation are quite important for getting these effects. One needs to meet neurons in a certain axis to get the effects of the subthreshold depolarization. This is more important for suprathreshold activation, for which one will get an action potential. When we do it at the subthreshold tonic level, it depends more or less completely on the right axis of the neuron[3]. This suggests that TDCS indeed modulates the synaptic strength in the cortex, and evidence from studies has suggested the involvement of intracortical neurons[4].

Along with these findings, it is also suggested that stimulation duration and intensity play a role in the physiological effects of TDCS. One will get a more central obsessed ATP or ATD induction range by prolonging stimulation duration and intensity. This also means that at a certain stimulation duration and intensity, one can get an over-activation of the system and might get a non-linear antagonistic effect of TDCS stimulation[3]. In conclusion, prolonged effects of TDCS can be achieved under certain conditions by increasing current density and stimulation duration along with repeated stimulation and pharmacological intervention[3].

TDCS safety

Within the last decade, a non-invasive brain stimulating technique called Transcranial direct current stimulating has emerged as a useful investigative ad therapeutic technique. Studies suggest TDCS safe, limited to skin irritation at the area of electrodes[5], and suggest that it can be efficacious in treating various psychiatric and neurological disorders[6].

However, several biophysical qualifications should be made in developing safety guidelines for TDCS[7]. One of these includes the awareness of the type of injury that occurs from electrical stimulation and what type of injury depends on the precise stimulation hardware and waveform applied[8,9]. Also, the harmful effect on the skin and brain of TDCS should be considered independently from the risk and mitigation standpoint rather than linking them together[7]. Toward this safety concern, the report of Liebetanz and Gottingen is a valuable contribution that suggests that the brain tissue damage was accessed by epicranial electrode stimulation in the rat model[10]. Another safety limit that one must be concerned about is preventing undesirable cognitive side effects that do not improve by preventing brain damage for TDCS electrodes. Because though to date, reports of TDCS have generally indicated only a transient improvement or impairment in performance concerning the modulation of cognitive functions[11].

TDCS enhances cognition

TDCS represents a potential intervention to enhance cognition across clinical populations, including mild cognitive impairment, among psychological and neurological disorders[12]. A randomized clinical trial suggests that anodal TDCS to the left dorsolateral prefrontal cortex (DLPFC) for 30 min over nine sessions could enhance memory[12]. Similarly, ten individuals with mild cognitive impairment show that anodal stimulation over left DLPFC significantly improves immediate and delayed picture recalls over an extended period of 1 month[13]. A growing body of research supports the idea of cognitive benefits in response to anodal TDCS in mild cognitive impairment[12].

TDCS is treating depression

Altered cortical activity and excitability in the prefrontal area have been seen in depression and major depressive disorder (MDD), along with dysfunction in distributed cortico-subcortical, hemispheric network. Results from studies of the early 1960s suggest a reduction in symptoms of depression with DC stimulation suggesting its efficacy. Therefore, it is hypothesized that the pathological state of depression, when altered with brain stimulation techniques, may offer a therapeutic target[14].

TDCS encompasses induction of relatively weak constant current flow through the cerebral cortex via scalp electrodes. As a result, cortical excitability and neural activity are modulated depending on the polarity of stimulation[14]. The early studies suggested an increase in neural activity in response to subthreshold DC stimulation when the anode was placed above or within the cortex. In contrast, a reduction in activity was observed when exposed to cathode polarity[15,16]. However, the effects of DC stimulation were not homogenous[17]. Recent studies suggest that TDCS might be useful in treating depression with appropriate current, size of electrodes, and employment of montages[18]. A double-blind clinical trial suggests that TDCS can have antidepressant effects with significantly larger reductions in depression with anodal TDCS of the left dorsolateral prefrontal cortex[19].

TDCS techniques have been used to examine the neural processes that underlie psychological processes, including working memory, language, enhancing cognition, spatial attention, and response selection[20]. TDCS opens a new perspective in treating major depressive disorder (MDD) because of its ability to modulate cortical excitability and induce long-lasting effects[21]. In 2009, Nitsche et al. discussed the effectiveness of TDCS by reviewing the results from clinical, controlled, pilot, randomized, double-blinded, and sham-controlled studies. The results from the studies suggest a significant positive effect of TDCS on the treatment of MDD[22].

In recent years, there has been an extreme rise in the number of TDCS studies that use the technique to gain a system-level understanding of the cortical substrates underlying changes in mood and behavior[21]. A recent review of 58 articles by Bennabi and Haffen in 2018, including meta-analysis, randomized control trials (RCTs), controlled studies, and open-label trials, suggest promising clinical and cognitive therapeutic effects of TDCS in MDD[21].

Discussion

With the enhancement claims about TDCS devices, there is a number of important experiments and technical issues regarding this device that are not discussed in any meaningful way. The TDCS devices should demonstrate a similar effect in a range of people before its implication in healthy or clinical populations[23]. However, the literature review revealed extensive between-and within-group variation suggesting its inconsistent effect among individuals[23]. Nitsche et al., 2004, reported a large between-group variation with a difference of 110%[21]. Intra-subject reliability reviews the lack of TDCS response reliability at the level of the individual but unfortunately, to date, it has not been explored in any literature[1]. However, it must be demonstrated that people respond to repeated sessions of TDCS similarly and predictably before this device can be meaningfully applied[1]. Sham stimulation and blinding focus on comparing the polarities of the anode excite/cathode inhibit the mechanism of TDCS, making it very difficult to

determine the true effect of each[1]. This issue draws attention to the importance of proper control and blinding practices in the literature on TDCS. Although the practitioners are aware of this comparative shortcoming use of various control stimulation procedures and are enthusiastically praising it, the use of these procedures has not always proven effective and reliable in varied TDCS protocols[23,24]. As pointed out in previous study that TDCS blinding, especially with the utilization of sham stimulation, is of utmost importance, but still, it isn't easy to achieve[25]. The motor and cognitive interference that highlighted the negative interference of the active motor or cognitive activity undertaken during or following TDCS, with or altogether abolishing the effects of stimulation[1]. Studies regarding this issue suggest that relatively simple and difficult-to-control thoughts or behaviors may affect the TDCS efficacy[1]. Finally, the issue regarding TDCS is electrical current influences. The issue highlighted the fact that a number of variables may influence the current flow and density to a great extent but have not been discussed in the literature regarding TDCS to date[1]. These ignored variables include the thickening of hair and the method of electrode attachment. However, many studies have discussed electrodes' positioning, current density, and stimulation duration in TDCS[26-28].

Conclusion

TDCS has the potential to improve cognition in a variety of clinical populations, including those with mild cognitive impairment due to psychological or neurological disorders. If the current, electrode size, and montages are carefully chosen, it may be useful in treating depression. TDCS provides a novel approach to treating major depressive disorder due to its ability to modulate cortical excitability and induce long-lasting effects.

Conflicts of Interest

The authors have no conflicts of interest.

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