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tACS as a promising therapeutic option for improving cognitive function in mild cognitive impairment: A direct comparison between tACS and tDCS

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ABSTRACT

Neuromodulation has gained attention as a potential non-pharmacological intervention for mild cognitive impairment (MCI). However, no studies have directly compared the effects of transcranial alternating current stimulation (tACS) with transcranial direct current stimulation (tDCS) on MCI patients. We aimed to identify the more promising and efficient therapeutic option between tACS and tDCS for cognitive enhancement in MCI patients. We compared the effects of gamma-tACS with tDCS on cognitive function and electroencephalography (EEG) in MCI patients. In this sham-controlled, double-blinded, repeated-measures study with the order of the stimulation counterbalanced across patients (n = 20), both gamma-tACS (40 H z) and tDCS were administered at the same intensity (2 mA) in the dorsolateral prefrontal cortex for 30 min. Cognitive tests (Stroop and Trail-Making-Test [TMT]) and EEG were performed before and after single-session stimulation. Gamma-tACS improved the Stroop-color in comparison with tDCS (p = .044) and sham (p = .010) and enhanced the TMT-B in comparison with sham (p = .021). However, tDCS was not significantly different from sham in changes of any cognitive test scores. In EEG analysis, gamma-tACS increased beta activity in comparison with sham and tDCS, whereas tDCS decreased delta and theta activity in comparison with sham. Gamma-tACS also increased beta 2 source activity in the anterior cingulate, compared to sham. The cognitive benefits of tACS in MCI patients appeared superior to those of tDCS. tACS facilitated cognitive function by increasing beta activity, while tDCS delayed the progression of MCI symptoms by decreasing slow-frequency activity. Thus, tACS could be used as a new therapeutic option for MCI.

1. Introduction

Mild cognitive impairment (MCI) is characterized by a cognitive decline to a greater extent than expected for an individual's age and education level such that everyday life is not affected (Winblad et al., 2004). MCI may represent a transitional state between normal aging and dementia (Petersen et al., 1999), and severe cognitive decline in this dementia-related condition could negatively affect independent daily living and social functioning (Lee et al., 2018). Thus, timely and effective interventions are required to improve cognitive function or delay the cognitive decline in patients with MCI (Xu et al., 2019). However, there are still no effective pharmacological treatments that can prevent cognitive symptoms or conversion to dementia (Cooper et al., 2013).

Transcranial electrical stimulation (tES) performed through painless and non-invasive neuro-modulation methods such as transcranial direct current stimulation (tDCS) has increasingly gained attention as a potential non-pharmacological intervention in MCI patients (Canter et al., 2016; Matsumoto and Ugawa, 2017). tDCS modulates spontaneous cortical activity with low-intensity currents (e.g., 1–2 mA), thereby altering plasticity in the stimulated brain regions (Birba et al., 2017). Since an altered dorsolateral prefrontal cortex (DLPFC) is the major neural basis responsible for the cognitive deficit in MCI (Liang et al., 2011; Murugaraja et al., 2017), tDCS over DLPFC could be an effective therapeutic option to modulate functional neural deficits in this pathology (Meinzer et al., 2015; Murugaraja et al., 2017). tDCS also could normalize the pathological electroencephalography (EEG) pattern in

Abbreviations: MCI, mild cognitive impairment; tES, transcranial electrical stimulation; tDCS, transcranial direct current stimulation; tACS, transcranial alternating current stimulation; DLPFC, dorsolateral prefrontal cortex; EEG, electroencephalography; AD, Alzheimer's disease; DSM, diagnostic and statistical manual of mental disorder; ANOVA, analysis of variance; TMT, Trail-Making-Test; sLORETA, standardized low resolution brain electromagnetic tomography.

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