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TRANSCRANIAL DIRECT CURRENT STIMULATION FOR COGNITIVE IMPAIRMENT IN MULTIPLE SCLEROSIS: A NARRATIVE REVIEW

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ABSTRACT

Background: Cognitive impairment is a common and disabling consequence of multiple sclerosis (MS), affecting information processing speed, memory, attention, and executive functioning. Despite its substantial impact on daily functioning and quality of life, effective therapeutic options remain limited. Transcranial direct current stimulation (tDCS), a portable, non-invasive neuromodulation technique that modulates cortical excitability and promotes neuroplasticity, has emerged as a potential adjunctive intervention for cognitive dysfunction in MS.
Objective: To summarize current evidence on the use of tDCS for cognitive impairment in MS and to explore factors contributing to variability in treatment response.
Methods: A literature search was conducted in PubMed to identify clinical studies evaluating the cognitive effects of tDCS in individuals with MS. Randomized controlled trials and observational studies were reviewed, and findings were synthesized narratively to provide a broad overview of the topic.
Results: Evidence suggests that tDCS may improve cognitive performance in MS, particularly in information processing speed, attention, working memory, and executive function. More consistent benefits have been reported when stimulation is combined with cognitive training. Treatment response may depend on baseline cognitive status, neurological disability, stimulation parameters, and targeted cortical regions. Considerable heterogeneity across studies limits direct comparison of findings.
Conclusions: tDCS appears to be a promising and well-tolerated approach for cognitive impairment in MS. However, methodological variability and small sample sizes preclude definitive conclusions. Larger, standardized trials are needed to clarify optimal stimulation protocols and identify reliable predictors of response.

KEYWORDS

Cognitive Impairment, tDCS, Multiple Sclerosis, Neuroplasticity, Neuromodulation

CITATION

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1. Introduction

1.1. Background

Multiple sclerosis (MS) is a chronic autoimmune, neuroinflammatory, and neurodegenerative disorder and one of the leading causes of long-term disability in young adults (Filippi et al., 2018). Patients affected by multiple sclerosis commonly demonstrate a broad range of functionally impairing symptoms, including persistent progressive cognitive decline. Cognitive impairment, particularly in information processing speed, memory, and executive functions, may progress independently of physical disability (Chiaravalloti & DeLuca, 2008). Together, these symptoms significantly limit social participation, occupational performance, and overall well-being. Despite their high clinical relevance, current pharmacological and non-pharmacological strategies provide only modest and inconsistent benefits, highlighting the need for more effective management approaches (Chen et al., 2020).

1.2. Prevalence of cognitive impairment in MS

Cognitive impairment is one of the most prevalent and disabling symptoms in MS and is believed to affect approximately 40–65% of MS patients, predominantly impacting information processing speed, memory, attention, and executive functions (Chiaravalloti & DeLuca, 2008). Cognitive deficits often occur independently of physical disability, emphasizing the need for early assessment and targeted management strategies to improve patients' quality of life.

1.3. What tDCS is?

Transcranial direct current stimulation (tDCS) has increasingly been explored as a potential therapeutic modality for ameliorating MS-related symptoms (Chmiel et al., 2025). tDCS is a neuromodulation technique that is non-invasive and safe for use in conscious, non-hospitalized patients. It is believed to modulate neuronal resting membrane potential through the delivery of low-intensity electrical currents. This form of modulation is generally associated with increased excitability of the motor cortex during anodal stimulation, whereas cathodal stimulation is linked to a reduction in cortical excitability. In contrast, non-motor cortical regions exhibit greater variability in polarity-specific stimulation effects (Nitsche & Paulus, 2000). Emerging evidence suggests that tDCS may alleviate cognitive deterioration and support cognitive performance and rehabilitative outcomes in neurological and psychiatric disorders, including mild Alzheimer's disease, by regulating neuronal activity and promoting neuroplastic processes (Bikson et al., 2016). Compared with alternative non-invasive neuromodulation methods, tDCS devices are highly portable, enabling broader population-level implementation and providing a practical solution for patients who require remote or home-based interventions (Dedoncker et al., 2016).

1.4. Purpose of the review

The purpose of this narrative review is to critically discuss and summarize the current evidence regarding the potential role of tDCS in alleviating cognitive impairment symptoms among individuals with MS. Given the limited and inconsistent therapeutic options available, tDCS has emerged as a potential non-invasive neuromodulatory intervention capable of modulating cortical excitability and supporting neuroplasticity. The review synthesizes findings from randomized controlled trials and observational studies, highlighting heterogeneity in study design, stimulation protocols, and reported cognitive outcomes, which may affect the interpretation and comparability of findings. It also discusses factors that may contribute to variability in treatment responses and emphasizes methodological limitations within the current evidence base, offering a perspective on areas for future research and clinical development.

2. Methodology

A structured literature search was conducted in the PubMed database to identify studies investigating the effects of tDCS on cognitive outcomes in individuals with MS. PubMed was chosen due to its broad coverage of biomedical literature and accessibility of peer-reviewed full-text articles. The search strategy included the following terms: (MS OR "Multiple Sclerosis") AND (tDCS OR "transcranial direct current stimulation"). The initial search yielded 403 records, which were screened by title and abstract for relevance, followed by full-text evaluation. After this process, 16 studies were included in the qualitative synthesis, comprising randomized controlled trials and observational studies that assessed cognitive outcomes following tDCS in MS patients. As this is a narrative review, the search was intended to provide broad coverage of the topic rather than a fully exhaustive synthesis. Potential limitations related to database selection, study heterogeneity, and variability in study design and outcome measures are discussed in the Limitations section.

3. Findings

3.1. Effects of tDCS on cognitive impairment in Multiple Sclerosis

Transcranial direct current stimulation has emerged as a promising non-invasive intervention for improving cognitive impairment in individuals with MS.

Research conducted by Riemann et al. demonstrated that tDCS enhances information processing speed (IPS) in patients with relapsing multiple sclerosis. Moreover, it has been shown that regionally targeted neuromodulation of the superior parietal cortex modulates IPS across both healthy and relapsing multiple sclerosis populations. Participants completed the computerized Symbol Digit Modalities Test during focal stimulation (1.5 mA), with active or brief sham application. In addition, the study revealed differential response to stimulation across participant groups. Anodal stimulation facilitated responses in healthy individuals, whereas cathodal stimulation led to prolonged latency. Patients demonstrated the opposite effect, with cathodal stimulation improving performance and anodal stimulation slowing responses. The efficacy of stimulation was influenced by baseline IPS performance. Cathodal tDCS improved responses in more impaired patients, while anodal tDCS was more effective in those with less severe impairment. These findings identify the superior parietal lobe as a causal node in IPS and establish clinically relevant predictors for individualized tDCS in multiple sclerosis. (Riemann et al., 2025)

Another study conducted by Charvet et al. investigated home-based tDCS combined with adaptive cognitive training (aCT) in patients with MS. Participants completed 30 supervised sessions targeting the left dorsolateral prefrontal cortex. Results showed that active tDCS + aCT led to significantly greater improvements in cognitive performance (BICAMS z-scores) compared with sham stimulation. The effect was most pronounced in participants with higher neurological disability, reflected in higher EDSS scores. These findings suggest that home-based tDCS paired with cognitive training is a feasible and effective approach to enhance cognition in MS. (Charvet et al., 2025)

In another study, Dahshan compared tDCS and transcranial magnetic stimulation (TMS) for symptoms in MS. In the study, patients with relapsing-remitting MS were assigned to receive either active tDCS, active TMS, or sham stimulation. The tDCS group underwent 2 mA anodal stimulation over the motor cortex for 20 minutes per day over a period of five consecutive days. Clinical outcomes were evaluated using the Fatigue Severity Scale, Visual Analogue Scale for pain, Beck Depression Inventory, and BICAMS cognitive assessment. Active tDCS significantly reduced fatigue, pain, and depression compared to sham, although no cognitive improvements were observed. These findings support the potential of short-term tDCS, particularly in home-based applications. For context, the TMS group in the same study showed similar improvements in fatigue, pain, and depression, indicating that multiple neuromodulation approaches may be effective, with TMS primarily suited to clinical settings. (Dahshan et al., 2025)

Another research conducted by Zakibakhsh et al. indicated that repeated prefrontal tDCS can beneficially modulate both cognitive and psychological outcomes in MS, supporting its further investigation in larger trials. Repeated prefrontal tDCS was applied to evaluate its effects on mental health, specifically quality of life, sleep, and psychological distress, and on cognitive function, including psychomotor speed, working memory, and attention or vigilance. Participants were randomized to receive either sham or tDCS targeting the left dorsolateral prefrontal cortex and right frontopolar cortex over 10 sessions of 20 minutes each. Real tDCS was associated with clinically significant benefits, improving quality of life, reducing sleep disturbances and psychological distress, and facilitating psychomotor speed, attention, and vigilance relative to sham. Improvements in cognitive and mental health measures were interrelated and predictive of each other. (Zakibakhsh et al., 2024)

In another study, Simani et al. evaluated the influence of repeated anodal tDCS (a-tDCS), cognitive training, and their combination on cognitive functioning in 80 individuals with MS. Ten consecutive daily sessions were administered to participants, who underwent cognitive evaluations at baseline and at 4 and 12 weeks post-intervention. The evaluation included episodic memory, attention, inhibitory control, working memory, and visuospatial skills. All active interventions significantly improved cognitive performance compared to sham, with some effects persisting at follow-up in the a-tDCS and a-tDCS with cognitive training groups. Training focused on cognitive skills alone led to temporary improvements in attentional capacity and inhibitory control, which were not sustained at subsequent follow-up assessments. (Simani et al., 2022)

Gholami et al. investigated the impact of multiple sessions of a-tDCS on cognitive performance and resting-state brain activity in 24 patients with MS. Eight consecutive daily sessions of either real or sham tDCS were administered over the left dorsolateral prefrontal cortex (DLPFC) in randomly assigned participants. Cognitive outcomes were assessed using the Cambridge Brain Sciences Cognitive Platform, and cortical activity was monitored with quantitative EEG. Real tDCS resulted in significant enhancements in reasoning and executive functions compared with sham. A trend toward improved attention was also observed, while resting-state brain activity remained unchanged. Evidence from this study supports the potential of anodal tDCS over the left DLPFC as a therapeutic strategy to mitigate cognitive deficits in individuals with MS. (Gholami et al., 2021)

Grigorescu et al. assessed the effects of bifrontal tDCS on general and social cognition in 11 right-handed patients with MS. Two blocks of daily 20-minute stimulation were administered to participants, with the anode and cathode positioned over the left and right prefrontal cortex, respectively. A three-week washout period separated the two blocks. Working memory and attention were assessed using the N-Back Test and SDMT, and social cognition with the Faux Pas and Eyes Tests. Accuracy on the 1-Back task improved after sham but not active tDCS, suggesting that cathodal stimulation over the right prefrontal cortex may have impaired working memory. No effects were seen on social cognition or SDMT performance. Given the small sample size and possible practice effects, these preliminary findings warrant further study in larger MS cohorts. (Grigorescu et al., 2020)

In a feasibility study investigating cognitive effects of remotely supervised transcranial direct current stimulation (RS-tDCS) in individuals with multiple sclerosis, Charvet et al. evaluated whether pairing RS-tDCS with at-home cognitive training enhances cognitive performance beyond cognitive training alone. Participants received ten 20-minute sessions of dorsolateral prefrontal cortex tDCS. delivered concurrently with structured cognitive training, and were compared with a control group undergoing the same training without stimulation. The RS-tDCS group demonstrated significantly superior outcomes in complex attention and intra-individual response variability, cognitive domains known to be sensitive markers of MS-related dysfunction. No group differences were observed for basic attention or standardized cognitive measures, suggesting that early cognitive benefits of tDCS may be domain-specific. These findings provide preliminary evidence that RS-tDCS may augment the effects of cognitive rehabilitation in MS, supporting its potential as a scalable and remotely deliverable neuromodulatory intervention for cognitive impairment. (Charvet et al., 2018)

In a randomized controlled study investigating cognitive enhancement in MS, Mattioli et al. evaluated whether pairing attention-focused cognitive training with anodal transcranial direct current stimulation (a-tDCS) over the left dorsolateral prefrontal cortex (DLPFC) could enhance training outcomes. Participants with MS with impairments in attention and IPS were randomized to receive either cognitive training combined with a-tDCS or cognitive training with sham stimulation across ten daily sessions. Neuropsychological assessments were performed at baseline, immediately post-treatment, and at six-month follow-up. Patients receiving a-tDCS demonstrated significantly greater improvements in attention and executive function at six months. Additionally, the a-tDCS group reached the most challenging cognitive training exercises in fewer sessions compared to sham, indicating accelerated training progression. These findings suggest that a-tDCS applied to the DLPFC during cognitive training can enhance the efficacy of neurorehabilitation by improving attention and executive functioning and reducing treatment duration in MS patients. (Mattioli et al., 2016)

Table 1. Summary of studies on a-tDCS effects on cognitive function in MS

Study	Participants / Design	Stimulation Parameters	Target Region	Key Outcomes
Riemann et al.	N = 64; preregistered, randomized, sham-controlled, triple-blind crossover (MS + healthy controls)	1.5 mA; anodal/cathodal; 20 min (active)	Superior parietal lobe	Demonstrated causal involvement of SPL in IPS; polarity-specific and impairment-dependent effects; strong blinding and no adverse effects.
Home-based tDCS + aCT (RCT)	MS patients; 30 supervised home sessions	Anodal tDCS; parameters not detailed here	Left DLPFC	Significant improvement in BICAMS scores; strongest effects in patients with higher EDSS; feasible home-based intervention.
Dahshan et al.	N = 30; randomized, single-blind (tDCS vs. TMS vs. sham)	2 mA; 20 min daily × 5 days	Motor cortex	tDCS reduced fatigue, pain, depression; no cognitive improvements; effects comparable to TMS.
Zakibakhsh et al.	N = 40; randomized, double-blind (real vs. sham)	1.5 mA; 20 min × 10 sessions	Left DLPFC + right frontopolar cortex	Improved QoL, sleep, psychological distress, psychomotor speed, attention, vigilance; cognitive and mental health improvements were interrelated.
Simani et al.	N = 80; randomized controlled	Anodal tDCS; 10 sessions	Left DLPFC	Improvements in memory, attention, inhibitory control, working memory, visuospatial skills; effects partially persisted at 12 weeks; cognitive training alone produced short-term gains only.
Gholami et al.	N = 24; randomized (real vs. sham)	Anodal tDCS; 8 daily sessions	Left DLPFC	Improved reasoning and executive function; trend toward better attention; no changes in resting-state EEG activity.

Grigorescu et al.	N = 11; cross-over, bifrontal montage	2 mA; 20 min; anode L-DLPFC / cathode R-PFC	Bifrontal	No improvements in social cognition; cathodal R-PFC may impair working memory; small sample, practice effects noted.
Charvet et al. (RS-tDCS)	Remotely supervised tDCS; N not specified here	1.5 mA; 20 min × 10 sessions	DLPFC	Improved complex attention and response variability; no effects on basic attention or standardized cognitive tests; supports scalable remote use.
Mattioli et al.	N = 20; randomized (a-tDCS + training vs. sham + training)	Anodal tDCS; 10 sessions	Left DLPFC	Enhanced attention and executive function post-treatment; long-term improvements in PASAT and WCST at 6 months; accelerated progress through training tasks.

4. Discussion

Across the reviewed studies, tDCS appears to have potential as a non-invasive neuromodulatory approach for mitigating cognitive deficits in individuals with MS, although reported effects vary depending on stimulation parameters, target regions, patient characteristics, and outcome measures. As suggested by Riemann et al., stimulation over the superior parietal lobe may affect information processing speed, with polarity- and impairment-dependent effects distinguishing patients from healthy controls (Riemann et al., 2025). Studies targeting the dorsolateral prefrontal cortex, particularly when combined with cognitive training, generally suggest improvements in domains such as psychomotor speed, attention, executive function, and working memory. Some evidence indicates that these cognitive benefits may be more pronounced in individuals with greater neurological disability, suggesting that baseline impairment could influence responsiveness to tDCS. tDCS may modulate cortical excitability and enhance neuroplasticity, potentially supporting improvements in cognitive domains sensitive to MS-related deficits. The combination of tDCS with cognitive training appears to further engage task-relevant neural circuits, producing more robust and sustained benefits, including in home-based or remotely supervised interventions. Feasibility and tolerability were consistently reported as favourable across studies, suggesting that repeated and even home-based applications may be safely implemented. However, findings across studies are not entirely consistent. Some studies report no cognitive changes, domain-specific improvements, or potential interference effects depending on stimulation polarity or montage. Variability in session number, intensity, blinding procedures, and cognitive tasks likely contributes to these heterogeneous outcomes.

These observations underscore the heterogeneity of stimulation protocols, cognitive domains assessed, and outcome measures, which should be carefully considered when interpreting and comparing results. Altogether, these findings highlight the need for standardized stimulation protocols, consistent cognitive assessments, and larger, well-controlled trials to clarify optimal parameters and identify reliable predictors of treatment response.

5. Conclusions

Current evidence suggests that tDCS may provide cognitive benefits for individuals with MS, particularly in domains such as attention, working memory, and processing speed. These effects appear to be enhanced when combined with cognitive training, and baseline cognitive status or neurological disability may influence responsiveness, supporting the potential for individualized stimulation protocols. Home-based or remotely supervised interventions have demonstrated feasibility and tolerability, indicating promise for scalable cognitive rehabilitation strategies (Charvet et al., 2025; Charvet et al., 2018). Nonetheless, variability across studies in stimulation parameters, cognitive domains assessed, outcome measures, and study designs limits the ability to draw definitive conclusions. Future research should prioritize standardized stimulation protocols, consistent cognitive assessments, and larger, well-controlled trials to clarify optimal parameters and identify reliable predictors of response. Addressing these gaps is essential for translating tDCS into routine clinical practice and maximizing its potential to alleviate cognitive deficits in individuals with MS.

6. Limitations

This narrative review has several limitations that should be considered when interpreting the findings. The literature search was conducted in a single database (PubMed), and as a narrative review, it was intended to support a broad perspective on the topic rather than provide a fully systematic and exhaustive identification of all available studies. Consequently, some relevant publications may not have been captured. Considerable heterogeneity exists across studies in terms of stimulation protocols, target regions, session number and intensity, and outcome measures, limiting direct comparability. Variability in cognitive assessments and the domains evaluated further complicates synthesis, particularly given the domain-specific effects observed in attention, working memory, and processing speed. Small sample sizes and differing follow-up durations in many studies also reduce statistical power and may affect the reliability of reported effects. Finally, several studies were preliminary or pilot investigations limiting the generalizability of their findings. These limitations highlight the need for cautious interpretation and underscore the importance of more standardized, adequately powered trials in future research.

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