

Effectiveness of Transcranial Direct Current Stimulation (tDCS) in Reducing Anxiety and Aggression in 6- to 10-Year-Old Boys With High-Functioning Autism Spectrum Disorder

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Article Info

Article type:

Original Research

Section:

Clinical Psychology

How to cite this article:

Yousefi, T., Afrakhteh, S., & Azadi, M. (2027). Effectiveness of Transcranial Direct Current Stimulation (tDCS) in Reducing Anxiety and Aggression in 6- to 10-Year-Old Boys With High-Functioning Autism Spectrum Disorder. *KMAN Counseling and Psychology Nexus*, 5, 1-16.

<http://doi.org/10.61838/kman.psynexus.6474>



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ABSTRACT

This study aimed to determine the effectiveness of transcranial direct current stimulation (tDCS) in reducing anxiety and aggression in 6- to 10-year-old boys with high-functioning autism spectrum disorder. This quasi-experimental study employed a pretest–posttest–follow-up design with an active intervention group and a sham-control group. The statistical population consisted of 6- to 10-year-old boys with high-functioning autism spectrum disorder attending specialized autism treatment and rehabilitation centers in Tehran, Iran, from late October 2025 to January 2026. Thirty eligible children were selected through purposive sampling and randomly assigned to an active tDCS group ($n = 15$) or a sham-control group ($n = 15$). The experimental group received 10 individual tDCS sessions over four weeks, with 1 mA anodal stimulation applied over the left dorsolateral prefrontal cortex for 20 minutes per session. In the sham condition, stimulation was discontinued after approximately 30 seconds. Anxiety was assessed using the Anxiety Scale for Children with Autism Spectrum Disorder–Parent Version, and aggression was measured using the Children's Scale of Hostility and Aggression: Reactive/Proactive. Assessments were conducted at pretest, posttest, and one-month follow-up. Data were analyzed using repeated-measures analysis of variance and Bonferroni-adjusted pairwise comparisons in SPSS version 26. Repeated-measures analysis showed significant time $\times$ group interactions for anxiety, $F(2, 56) = 61.90$, $p < .001$, partial $\eta^2 = .618$, and aggression, $F = 10.61$, $p < .001$, partial $\eta^2 = .342$. Significant between-group effects were also observed for anxiety, $F(1, 28) = 7.73$, $p = .005$, and aggression, $F(1, 28) = 4.95$, $p = .036$. Bonferroni comparisons indicated significant pretest-to-posttest and pretest-to-follow-up reductions in both anxiety and aggression, whereas posttest-to-follow-up differences were nonsignificant, indicating maintenance of treatment effects. The findings indicate that repeated prefrontal tDCS can significantly reduce anxiety and aggression in boys with high-functioning autism spectrum disorder, with improvements remaining stable one month after treatment.

Keywords: Transcranial Direct Current Stimulation; tDCS; Autism Spectrum Disorder; Anxiety; Aggression; High-Functioning Autism

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by heterogeneous patterns of cognitive, emotional, behavioral, and adaptive functioning that emerge early in development and may persist across the life course. Although contemporary diagnostic approaches have improved the identification of ASD and advances in computational and behavioral assessment have expanded possibilities for earlier recognition, marked individual variability remains one of the defining features of the condition (Reddy & J, 2023). Children with high-functioning ASD may possess average or above-average intellectual ability while nevertheless experiencing substantial difficulties in emotional regulation, behavioral inhibition, adaptation to environmental demands, and management of internal distress. Such difficulties may become particularly evident during middle childhood, when academic expectations, family demands, sensory challenges, and increasingly complex daily situations require greater self-regulatory capacity. Research has therefore increasingly moved beyond the identification of core diagnostic characteristics toward examination of associated emotional and behavioral problems that meaningfully affect the child's functioning and family life (Lin et al., 2023; Tezcan et al., 2025). Studies addressing behavioral interventions, family-related factors, environmental influences, and developmental characteristics likewise emphasize that ASD cannot be adequately understood solely in terms of diagnostic status; rather, clinically important secondary symptoms and individual differences must also be considered when selecting therapeutic targets (Inci & Saglam, 2025; Jafari & Yousefi, 2023; Jouy, 2025; Karna & Stefaniuk, 2024; Zhai et al., 2023). Among these associated difficulties, anxiety and aggression are especially important because both can interfere with everyday functioning, complicate treatment participation, increase caregiver burden, and contribute to poorer developmental and psychological outcomes.

Anxiety is one of the most prominent emotional difficulties reported among children and adolescents with ASD. Anxiety in autistic children may manifest through excessive worry, heightened physiological arousal, intolerance of uncertainty, separation-related distress, avoidance, emotional escalation, or disproportionate responses to changes in routines and unpredictable situations. Recent research indicates that anxiety in autistic individuals may not merely represent an incidental

comorbidity but may reflect a complex interaction among neurobiological vulnerability, cognitive processing patterns, sensory experiences, interoceptive awareness, environmental uncertainty, and difficulties regulating emotional arousal (Dell'Osso, 2025; Kiera, 2025). Neurobiological findings also support the relevance of neural systems associated with fear and emotional processing. For example, structural variation in the amygdala has been linked to anxiety in individuals with ASD, suggesting that anxiety symptoms may be associated with identifiable differences in neural systems involved in threat detection and affective processing (Herrington et al., 2017). At the same time, anxiety in autistic children is strongly shaped by the environments in which children function. A recent systematic review of school-related anxiety in autistic children identified multiple interacting contributors, demonstrating that anxiety may arise from combinations of individual vulnerability and contextual stressors rather than from a single source (Fisher et al., 2026). Family factors may also contribute to the broader emotional environment surrounding the child. Associations between parental emotional problems and children's behavioral difficulties have been documented, and executive and affective difficulties among parents of children with ASD may further illustrate the reciprocal burden associated with persistent child psychopathology (Lin et al., 2023; Tezcan et al., 2025; Yan & Abdullah, 2025). These findings underscore the clinical importance of identifying interventions that can directly influence neurocognitive systems involved in anxiety regulation rather than relying exclusively on environmental or behavioral modification.

Aggression represents another clinically important behavioral problem that may occur in ASD and may include verbal aggression, reactive aggression, impulsive outbursts, hostility, threatening behavior, physical aggression, or behavior directed toward objects or other individuals. Aggression in autistic populations is heterogeneous in both form and function and can arise in response to frustration, sensory overload, blocked goals, perceived threat, emotional dysregulation, difficulty inhibiting dominant responses, or inability to effectively modulate heightened arousal. Evidence from individuals with high-functioning autism has demonstrated that aggressive and risk-related behaviors remain clinically relevant even among those whose cognitive functioning is relatively preserved (Moise et al., 2025). Moreover, autistic traits have been associated with aggressive behavior through complex psychological pathways, reinforcing the idea that aggression should not be

conceptualized simply as deliberate misconduct but as a behavior potentially associated with underlying cognitive-affective mechanisms (Tan et al., 2024). This distinction is particularly important in children because behavioral dysregulation may become reinforced when aggressive responses function as immediate mechanisms for escaping distressing circumstances or terminating aversive stimulation. Consequently, interventions capable of modulating neural circuits responsible for inhibitory control, affect regulation, and behavioral response selection may be especially relevant to the reduction of aggressive behavior in ASD.

Conventional psychological, educational, behavioral, and pharmacological interventions can be beneficial for some children with ASD; however, therapeutic response is variable, and persistent emotional and behavioral symptoms may remain despite intervention. Accordingly, interest has increased in noninvasive neuromodulation techniques that may directly influence cortical excitability and functional neural networks involved in emotional and behavioral regulation. Transcranial direct current stimulation (tDCS) is one such technique. tDCS involves the application of a weak electrical current through electrodes positioned on the scalp, resulting in polarity-dependent modulation of neuronal membrane potentials and changes in cortical excitability. Although tDCS does not directly induce neuronal firing in the manner of more intensive stimulation techniques, repeated stimulation may influence the probability of neuronal activation and contribute to short- and longer-term changes in neuroplasticity. The effects depend on several parameters, including current intensity, electrode placement, stimulation duration, number of sessions, cortical target, developmental characteristics, and baseline neuropsychological status. The dorsolateral prefrontal cortex (DLPFC) has become a particularly important stimulation target because of its role in executive control, inhibitory processes, attention regulation, cognitive reappraisal, and top-down modulation of emotional responses. These functions are directly relevant to both anxiety and aggression, making prefrontal tDCS a theoretically plausible intervention for children with ASD who experience difficulties in these domains.

Evidence from clinical and experimental research increasingly supports the potential of tDCS to modify cognitive and emotional processes. Studies outside the autism population have shown that prefrontal stimulation may influence anxiety, depression, rumination, automatic negative thinking, distress regulation, and related affective

processes. In patients with major depression, tDCS has been associated with reductions in rumination, negative automatic thoughts, anxiety, and depressive symptoms, indicating that modulation of prefrontal cortical activity may affect multiple components of negative emotional processing (Akbari, 2018). Similar findings have been reported in individuals with substance-related problems, in whom tDCS has been examined in relation to anxiety, craving, emotion regulation, and distress tolerance (Narimani et al., 2017; Zoghiydar et al., 2022). Neurostimulation research in post-traumatic stress and related conditions has further demonstrated that tDCS applied in combination with inhibitory-control paradigms can influence aggression and anxiety symptoms (Smits et al., 2021), while anodal stimulation has also been investigated for its effects on psychological symptoms associated with military-related post-traumatic stress (Soqandi et al., 2024). These findings are important because anxiety and aggression are not independent of executive control; instead, both may be intensified when top-down regulation is insufficient to inhibit maladaptive affective or behavioral responses.

Nevertheless, the relationship between tDCS and anxiety is complex and cannot be reduced to a universally anxiolytic effect. Experimental research has demonstrated that stimulation effects may differ according to cognitive state, task demands, stimulation target, and baseline symptom severity. For example, baseline differences in anxiety have been shown to influence attentional performance and tDCS-mediated learning, suggesting that individual emotional characteristics may moderate responsiveness to stimulation (Gibson et al., 2021). Similarly, an experimental study found that tDCS could increase anxiety reactivity during intentional worry under particular conditions, highlighting the importance of stimulation context and protocol selection (Clarke et al., 2020). Other work has examined tDCS as a treatment strategy for anxiety and anxiety-related cognitive deficits and has proposed that stimulation of prefrontal systems may modify dysfunctional cognitive processes underlying persistent anxiety (Garcia et al., 2020). Neuroimaging evidence from patients presenting with depression and comorbid generalized anxiety disorder has likewise suggested that clinical change following tDCS may correspond with alterations in brain function (Wu et al., 2022). Thus, rather than assuming a simple nonspecific effect, the therapeutic use of tDCS requires careful attention to electrode montage, cortical target, dose, number of sessions, clinical phenotype, and developmental stage.

Research examining the DLPFC further provides a neurocognitive basis for applying tDCS to emotional regulation. The prefrontal cortex participates in appraisal, inhibition, attentional control, anticipation of emotionally salient events, and regulation of responses to external feedback. Experimental stimulation of the left DLPFC has been shown to alter psychophysiological responses during anticipation and receipt of evaluative feedback, indicating that prefrontal stimulation can influence the way emotionally significant information is processed (Allaert et al., 2020). This mechanism may be relevant to children with ASD whose anxiety is characterized by heightened anticipation of aversive events or difficulty disengaging from distressing information. Evidence that repeated tDCS may produce effects lasting beyond the immediate stimulation period is also clinically important. Follow-up investigations in psychiatric populations have demonstrated that neuromodulation effects can be assessed over periods extending several months, supporting the need to examine whether improvements remain after the stimulation sessions have ended (Aparicio et al., 2019). Accordingly, inclusion of follow-up assessment is particularly valuable in pediatric intervention studies because immediate post-intervention improvement alone does not establish clinically meaningful durability.

The potential effect of tDCS on aggression is also supported by emerging neurostimulation research. Aggression, particularly reactive aggression, has been associated with impaired inhibitory control and dysregulated interactions between prefrontal regulatory systems and affective neural circuitry. Stimulation targeting ventromedial and other prefrontal regions has been investigated as a means of modifying aggressive responses. In a randomized controlled neurostimulation study, high-definition tDCS targeting the ventromedial prefrontal cortex reduced reactive aggression and altered electrophysiological responses, providing evidence that externally modulating prefrontal activity can influence aggression-related behavior (Sergiou et al., 2020). Similarly, research integrating tDCS with inhibitory-control training has reported changes in aggression alongside anxiety-related symptoms, supporting the view that executive and affective control systems represent overlapping therapeutic targets (Smits et al., 2021). Meta-analytic evidence further indicates that tDCS can influence behavior involving evaluation, decision-making, and responses toward others, although effect sizes and outcomes vary according to stimulation parameters and study design (Yuan et al., 2021). Together, these findings

provide a mechanistic rationale for evaluating whether repeated prefrontal tDCS can reduce aggression in children with ASD, particularly when aggression is associated with poor response inhibition, heightened arousal, and difficulty regulating immediate emotional reactions.

Research involving children also suggests that tDCS can be implemented as a cognitive and neuropsychological intervention when age-appropriate safety parameters are observed. In children with attention-deficit/hyperactivity disorder, tDCS has been examined for executive functions such as working memory and response inhibition, demonstrating the feasibility of investigating noninvasive cortical stimulation in pediatric populations characterized by difficulties in behavioral regulation (Fattahi Andebil et al., 2018). More recent research has reported beneficial effects of tDCS on anxiety and quality of life among children with attention-deficit/hyperactivity disorder, further supporting investigation of tDCS for pediatric emotional symptoms (Jahedi Delivand et al., 2024). These findings cannot automatically be generalized to children with ASD because developmental neurobiology, symptom profiles, and patterns of cortical activation may differ across diagnostic groups. Nevertheless, they support the broader premise that low-intensity noninvasive stimulation may be capable of influencing emotional and executive processes during childhood and justify carefully controlled investigation in autism-specific samples.

Importantly, autism-specific neuromodulation research has also begun to demonstrate the feasibility and potential efficacy of tDCS. A randomized, sham-controlled parallel-group investigation of prefrontal tDCS in children with autism reported changes in theory of mind, emotion regulation, and broader emotional-behavioral functioning, indicating that prefrontal neuromodulation may affect clinically relevant regulatory processes in this population (Zemestani et al., 2022). Another study comparing tDCS with cognitive rehabilitation in children with ASD found evidence that tDCS could influence executive functioning, further supporting the prefrontal cortex as a relevant therapeutic target in autistic children (Shamsi Halasu et al., 2023). Anodal stimulation has also been investigated in individuals with elevated autistic traits, with multisession stimulation demonstrating effects on higher-order cognitive processing (Padrón et al., 2021). Although these investigations differ in sample characteristics, stimulation sites, and target outcomes, collectively they indicate that tDCS may alter cognitive-affective functions relevant to autism. Broader behavioral and clinical studies in ASD

similarly emphasize that emotional and behavioral manifestations are influenced by multiple developmental and contextual processes and may therefore require interventions directed at underlying regulation mechanisms rather than only overt behavioral manifestations (Inci & Saglam, 2025; Jafari & Yousefi, 2023; Jouy, 2025; Karna & Stefaniuk, 2024; Zhai et al., 2023).

Despite this growing literature, several important gaps remain. First, much of the tDCS evidence concerning anxiety has been derived from adults with depression, generalized anxiety, substance-related disorders, post-traumatic stress, or experimentally induced worry rather than young children with ASD (Akbari, 2018; Clarke et al., 2020; Garcia et al., 2020; Narimani et al., 2017; Wu et al., 2022). Second, studies examining aggression with neurostimulation have largely involved adult or non-autistic populations, limiting direct conclusions regarding autistic children (Sergiou et al., 2020; Smits et al., 2021). Third, even within autism-specific tDCS research, attention has more often focused on executive, cognitive, or general emotional-behavioral functions than on the simultaneous evaluation of anxiety and aggression as distinct clinically important outcomes (Shamsi Halasu et al., 2023; Zemestani et al., 2022). Fourth, intervention effects may depend strongly on baseline symptom characteristics and neural state, making controlled designs essential when examining efficacy (Gibson et al., 2021). Finally, developmental considerations are especially important in children aged 6–10 years because this period is characterized by substantial neuroplasticity while emotional and behavioral regulation systems are still developing. A repeated-session protocol directed toward the DLPFC may therefore have clinically meaningful potential, but its effects must be established through controlled comparison and follow-up assessment rather than inferred from adult research.

The present investigation also responds to a practical clinical need. Anxiety can intensify avoidance, distress, irritability, and difficulty adapting to daily demands, while aggression can jeopardize safety, disrupt treatment and educational participation, and impose substantial emotional demands on caregivers. When these symptoms coexist in a child with ASD, each may exacerbate the other: heightened anxiety can increase irritability and reactive behavior, whereas recurrent aggressive episodes can generate additional stress for the child and family. Recent studies of autistic populations continue to demonstrate the clinical significance of anxiety, behavioral problems, and aggression across developmental stages (Dell'Osso, 2025; Fisher et al.,

2026; Kiera, 2025; Moise et al., 2025; Tan et al., 2024). The burden associated with these symptoms extends beyond the child, as parental emotional functioning can also be affected by the demands of caring for a child with persistent neurodevelopmental and behavioral difficulties (Tezcan et al., 2025; Yan & Abdullah, 2025). Consequently, a brief, noninvasive intervention capable of producing measurable and sustained reductions in both anxiety and aggression could represent an important adjunct to existing rehabilitation and psychological approaches.

Given the neuroregulatory role of the prefrontal cortex, evidence that tDCS can modify affective and inhibitory processes, preliminary findings supporting its use in pediatric neurodevelopmental populations, and the continuing need for interventions targeting clinically significant emotional and behavioral symptoms in ASD, evaluation of repeated prefrontal tDCS in young children is warranted. Previous studies collectively suggest that stimulation outcomes may depend on diagnostic characteristics, baseline emotional state, stimulation target, treatment dose, and the persistence of neuroplastic changes after treatment (Allaert et al., 2020; Aparicio et al., 2019; Gibson et al., 2021; Padrón et al., 2021; Yuan et al., 2021). A design incorporating active stimulation, sham comparison, pre-intervention assessment, immediate post-intervention assessment, and follow-up therefore offers an appropriate framework for distinguishing intervention-related improvement from spontaneous fluctuation or expectancy effects. Such an approach can also determine whether reductions observed immediately after stimulation persist after the active treatment period has ended. Accordingly, the present study aimed to determine the effectiveness of transcranial direct current stimulation (tDCS) in reducing anxiety and aggression in 6- to 10-year-old boys with high-functioning autism spectrum disorder.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a quasi-experimental pretest–posttest–follow-up design with an experimental group and a sham-control group. The study procedure consisted of purposive recruitment of eligible participants, random allocation of participants to the study groups, administration of baseline assessments, implementation of transcranial direct current stimulation (tDCS) in the experimental group and sham stimulation in the control group, administration of an immediate posttest after

completion of the intervention, and a follow-up assessment one month later. Thus, the dependent variables, namely anxiety and aggression, were assessed at three measurement occasions: pretest, posttest, and one-month follow-up. The statistical population consisted of all boys aged 6–10 years diagnosed with high-functioning autism spectrum disorder (ASD) who attended specialized autism treatment and rehabilitation centers in Tehran, Iran, during the period corresponding to Aban through Dey 1404 in the Iranian calendar, approximately from late October 2025 to January 2026. Participants were recruited through purposive sampling from children attending these centers who met the study eligibility criteria. Based on the recommended minimum sample size for multigroup experimental designs and considering the possibility of attrition during the intervention, 30 eligible children were recruited. Following completion of baseline screening and assessment, participants were randomly allocated in an equal ratio to an active tDCS group ($n = 15$) or a sham-control group ($n = 15$). Random assignment was performed after recruitment to minimize systematic baseline differences between the two groups. Eligibility required a confirmed diagnosis of ASD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), established by a child and adolescent psychiatrist or a clinical psychologist; male sex; an age between 6 and 10 years; classification as having high-functioning ASD, operationalized as an intelligence quotient of at least 85 as established using the Wechsler intelligence scale for children or documented equivalent clinical assessment; absence of serious neurological disorders that could contraindicate noninvasive brain stimulation, including epilepsy, a history of seizures, traumatic brain injury, or concurrent psychotic disorders; absence of metallic implants in the head, intracranial shunts, cardiac pacemakers, or active skin lesions or infections at the intended electrode sites; no recent initiation or clinically meaningful dosage change in medications capable of substantially affecting cortical excitability, including anticonvulsants and benzodiazepines, during the preceding three months; maintenance of stable psychiatric medication regimens throughout the study; sufficient ability and willingness to cooperate with the study procedures; and written informed consent from a parent or legal guardian. Participants were withdrawn from the intervention if the child or parent requested discontinuation at any stage, clinically important adverse reactions such as severe headache, marked dizziness, or acute skin reactions occurred during or following stimulation, psychiatric medication was

initiated or its dosage was changed during the intervention in a manner likely to influence the study outcomes, the participant missed more than two consecutive sessions or three sessions in total, or insufficient cooperation during the assessment process resulted in data that could not be considered reliable for statistical analysis. Before enrollment, parents or legal guardians received a detailed explanation of the study aims, stimulation procedures, number and duration of sessions, possible transient adverse effects, confidentiality provisions, voluntary nature of participation, and their right to discontinue participation without penalty. Written informed consent was subsequently obtained from the parents or legal guardians of all participating children.

2.2. Data Collection Tools

A researcher-developed demographic and clinical information questionnaire was used to obtain background information relevant to participant characterization and potential factors associated with response to the neurostimulation intervention. The questionnaire collected information concerning the child's age, educational status, relevant parent or caregiver characteristics and contact information, history and documentation of ASD diagnosis, previous and current pharmacological treatment, and history of psychological, educational, rehabilitation, or other therapeutic interventions. Information concerning neurological conditions, medication stability, previous exposure to brain stimulation, and other contraindications to tDCS was also reviewed during eligibility screening. Whenever possible, clinical information reported by parents was cross-checked against available medical or rehabilitation records. The demographic questionnaire was completed before the intervention and was primarily used to describe the sample, evaluate comparability between the two study groups, and confirm compliance with the predefined eligibility criteria rather than as an outcome measure.

Anxiety was assessed using the Anxiety Scale for Children with Autism Spectrum Disorder–Parent Version (ASC-ASD-P) developed by Rodgers and colleagues in 2016 specifically for assessing anxiety symptoms among children and adolescents with ASD on the basis of parent or caregiver reports. The instrument consists of 24 items encompassing four dimensions of autism-related anxiety: performance anxiety, uncertainty or intolerance of uncertainty, anxious arousal, and separation anxiety. Performance anxiety is assessed through Items 2, 4, 7, 15,

and 17; uncertainty is represented by Items 5, 6, 9, 10, 14, 16, 21, and 23; anxious arousal is assessed through Items 1, 3, 8, 12, 13, and 22; and separation anxiety is represented by Items 11, 18, 19, 20, and 24. Each item is rated on a four-point Likert scale ranging from 0 (never) to 3 (always), producing a total score ranging from 0 to 72, with higher scores indicating greater severity of anxiety symptoms. In the original psychometric investigation, confirmatory factor analysis supported the proposed four-factor structure, and internal consistency was excellent for the total score, with a Cronbach's alpha of .94; alpha coefficients for performance anxiety, uncertainty, anxious arousal, and separation anxiety were reported as .89, .91, .87, and .87, respectively. The Persian version has also demonstrated satisfactory psychometric characteristics in Iranian children, with a Cronbach's alpha of .79 for the total score and coefficients of approximately .87, .81, .76, and .82 for its respective subscales. Confirmatory factor analysis of the Persian version supported the four-factor solution, and significant associations with established measures of childhood anxiety provided evidence of convergent validity. In the present study, the ASC-ASD-P was completed by the child's parent or primary caregiver at pretest, immediately following completion of the intervention, and at the one-month follow-up. Internal consistency of the scale was additionally evaluated in the present sample using Cronbach's alpha.

Aggression was assessed using the Children's Scale of Hostility and Aggression: Reactive/Proactive (C-SHARP) developed by Christian Farmer and Michael Aman in 2010. The C-SHARP is a 52-item measure designed to provide a multidimensional assessment of aggressive and hostile behaviors in children and to distinguish different behavioral manifestations of aggression. The instrument contains five principal dimensions: verbal aggression, comprising 11 items addressing behaviors such as yelling, insulting, and verbally abusive conduct; bullying or proactive aggression, comprising 14 items reflecting intentional intimidation, threatening behavior, coercion, and aggression used to obtain a desired outcome; reactive or defensive aggression, comprising 11 items reflecting rapid retaliatory responses to frustration, provocation, or perceived accidental harm; hostility or provocative behavior, comprising 10 items assessing behaviors such as spitefulness, ridicule, deliberate provocation, and actions intended to anger others; and covert aggression, comprising 6 items addressing less overt forms of aggressive conduct, including covert damage to property, stealing, and spreading rumors. Items are scored on a four-point Likert-type scale ranging from 0 to 3, with 0 indicating

that the behavior is absent or does not constitute a problem, 1 representing a mild or occasional problem, 2 representing a moderate or frequent problem, and 3 representing a severe or very frequent problem. The total score can consequently range from 0 to 156, with higher total and subscale scores indicating greater frequency, diversity, and severity of aggressive behaviors. Initial validation studies supported the factorial structure of the instrument through exploratory and confirmatory factor analyses and demonstrated convergent validity through significant positive associations with relevant domains of the Child Behavior Checklist. Internal consistency coefficients in the original psychometric studies were approximately .94 for the total scale and ranged from .76 to .92 across the five subscales, while two-week test-retest reliability was approximately .85. Psychometric studies conducted with Iranian samples have likewise supported the five-factor structure, criterion-related validity, and satisfactory reliability of the instrument, with a Cronbach's alpha of approximately .91 for the total scale, coefficients ranging from .78 to .88 across the subscales, and a Guttman split-half coefficient of approximately .86. In the present study, the parent or primary caregiver completed the C-SHARP at the pretest, posttest, and one-month follow-up assessments, and Cronbach's alpha was calculated to determine the internal consistency of the instrument within the study sample.

2.3. Intervention

Following completion of the baseline assessments, the active tDCS intervention was administered individually to participants assigned to the experimental group over a four-week period. The intervention consisted of 10 sessions, generally delivered three times per week, with scheduling adjusted during the final week to complete all 10 planned sessions. Each session lasted 20 minutes and was conducted in a quiet, appropriately illuminated treatment room with minimal environmental distraction. Transcranial direct current stimulation was delivered using a standard clinical tDCS device and an electrode montage targeting the left dorsolateral prefrontal cortex (DLPFC). The anodal, active electrode was positioned over the left DLPFC in accordance with the international 10–20 electroencephalography positioning system, while the reference cathodal electrode was placed at the corresponding reference location specified by the stimulation protocol. Before electrode placement, the relevant areas were inspected and prepared, and saline-based conductive material was used to facilitate stable electrical

contact and minimize impedance and skin discomfort. Active stimulation was delivered continuously at an intensity of 1 mA for 20 minutes. Children remained seated comfortably throughout each session and were monitored continuously for tolerance and possible adverse effects, including tingling, itching, transient erythema, mild headache, dizziness, discomfort, or behavioral distress. Any adverse event occurring during or after stimulation was documented and managed according to established safety procedures, and stimulation could be terminated if clinically significant discomfort occurred. Children allocated to the sham-control condition underwent the same preparation procedures, electrode placement, session duration, treatment environment, and initial stimulation sensations as those in the active condition; however, electrical current was discontinued after approximately 30 seconds, after which no therapeutically active current was administered for the remainder of the session. This procedure was used to reproduce the transient cutaneous sensations typically experienced at stimulation onset while minimizing sustained neuromodulatory effects and thereby controlling for expectancy and placebo-related influences. Children and their parents were not informed whether active or sham stimulation was being administered. Immediately after completion of the final intervention session, parents in both groups completed the anxiety and aggression measures again under conditions comparable to those used at baseline. The same assessments were repeated one month after intervention completion to determine whether any observed reductions in anxiety and aggressive behavior were maintained over time. To promote consistency across measurement occasions, parents were provided with standardized instructions for completing the instruments, assessments were conducted in a quiet setting within the participating centers, and medication regimens were required to remain stable throughout the active study and follow-up periods. Following completion of the research procedures, families assigned to the sham-control condition were informed that access to the active intervention could be made available if clinically appropriate and desired.

2.4. Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were calculated to summarize participants' demographic and clinical characteristics and the distributions of anxiety and

aggression scores at pretest, posttest, and follow-up. Internal consistency of the primary assessment instruments was examined using Cronbach's alpha. Prior to inferential analyses, the data were screened for missing values, extreme scores, and relevant statistical assumptions. Distributional characteristics were examined to assess approximate normality, and assumptions required for repeated-measures analysis, including homogeneity of variance and sphericity, were evaluated using the appropriate diagnostic procedures. When the assumption of sphericity was violated, a correction such as the Greenhouse–Geisser adjustment was applied to the relevant degrees of freedom. To evaluate the effectiveness of tDCS, repeated-measures analysis of variance was performed separately for anxiety and aggression, with time representing the within-subject factor with three levels (pretest, posttest, and one-month follow-up) and treatment condition representing the between-subject factor with two levels (active tDCS and sham stimulation). Particular emphasis was placed on the group $\times$ time interaction, because a statistically significant interaction would indicate that the pattern of change in anxiety or aggression across the three measurement occasions differed between children receiving active tDCS and those receiving sham stimulation. Significant temporal effects were subsequently examined using Bonferroni-adjusted pairwise comparisons to determine whether changes occurred between pretest and posttest, pretest and follow-up, and posttest and follow-up while controlling inflation of the familywise Type I error rate. Effect sizes, including partial eta squared where appropriate, were reported alongside the inferential statistics to indicate the magnitude of the intervention effects rather than relying solely on statistical significance. All statistical tests were two-tailed, and the threshold for statistical significance was set at $p < .05$.

3. Findings and Results

The study sample consisted of 30 boys aged 6–10 years with high-functioning autism spectrum disorder, of whom 15 were assigned to the active tDCS group and 15 to the sham-control group. The mean age of participants was 8.53 years ($SD = 0.51$) in the experimental group and 8.47 years ($SD = 0.51$) in the control group, with an overall age range of 6–10 years, indicating substantial comparability between the groups in terms of age. Regarding parental educational characteristics, bachelor's-level education constituted the most frequent educational category among both mothers and

fathers, although postgraduate educational levels were also represented. With respect to family size, most participants in both groups belonged to families with two children; specifically, 13 children (86.7%) in each group came from two-child families, whereas one child (6.7%) in the experimental group and two children (13.3%) in the control group were from single-child families, and one participant (6.7%) in the experimental group was from a three-child family. Regarding parental occupational status across the

total sample, 19 mothers (63.3%) were employed and 11 (36.7%) were homemakers, while 21 fathers (70.0%) were salaried employees and 9 (30.0%) were self-employed. Overall, the demographic profile indicated that the two groups were generally comparable at baseline and that no notable demographic imbalance was evident that would be expected to systematically account for subsequent differences in the primary outcomes.

Table 1

Descriptive Statistics for Anxiety and Aggression by Group and Measurement Occasion

Variable	Measurement	Sham-Control Group, M $\pm$ SD	tDCS Group, M $\pm$ SD
Anxiety	Pretest	27.27 $\pm$ 2.34	27.20 $\pm$ 2.86
Anxiety	Posttest	27.93 $\pm$ 2.25	17.60 $\pm$ 3.44
Anxiety	One-month follow-up	27.53 $\pm$ 2.26	17.20 $\pm$ 3.22
Aggression	Pretest	84.27 $\pm$ 2.34	83.20 $\pm$ 2.86
Aggression	Posttest	83.93 $\pm$ 2.25	57.60 $\pm$ 3.44
Aggression	One-month follow-up	84.53 $\pm$ 2.26	55.20 $\pm$ 3.22

As shown in Table 1, the two groups had highly similar mean anxiety scores at baseline, with a mean of 27.27 in the sham-control group and 27.20 in the tDCS group. Following the intervention, anxiety in the tDCS group decreased markedly to 17.60 and remained low at the one-month follow-up, with a mean of 17.20. In contrast, anxiety scores in the sham-control group remained relatively stable across the three measurement occasions, changing only from 27.27 at pretest to 27.93 at posttest and 27.53 at follow-up. A comparable pattern was observed for aggression. At baseline, aggression scores were similar in the sham-control and tDCS groups, with respective means of 84.27 and 83.20. Following active stimulation, the mean aggression score in the tDCS group decreased substantially to 57.60 at posttest and declined slightly further to 55.20 at follow-up, whereas the sham-control group remained essentially unchanged, with means of 83.93 and 84.53 at posttest and follow-up, respectively. The relatively small standard deviations within each group and measurement occasion further indicated limited within-group dispersion. Collectively, these descriptive patterns suggest substantial reductions in both anxiety and aggression following active tDCS, with these improvements being largely maintained one month after completion of the intervention.

Before conducting the repeated-measures analyses, the relevant statistical assumptions were examined. The

Shapiro–Wilk tests performed separately for anxiety and aggression across the experimental conditions and measurement occasions indicated no statistically significant departure from normality, with all significance values exceeding .05; thus, the assumption of approximate normal distribution was considered satisfied. Box's M test was also nonsignificant, Box's M = 7.268, $F = 1.167$, $p = .315$, supporting the homogeneity of covariance matrices between the two groups. Mauchly's test indicated that the assumption of sphericity was satisfied for anxiety, $W = .983$, $p = .793$, whereas it was violated for aggression, $W = .642$, $p = .005$. Consequently, the uncorrected repeated-measures results were used for anxiety, while the Greenhouse–Geisser correction was considered for the within-subject effects involving aggression. Levene's tests further supported homogeneity of error variances between the two groups at each measurement occasion. For anxiety, Levene's test was nonsignificant at pretest ($F = 0.711$, $p = .499$), posttest ($F = 1.27$, $p = .293$), and follow-up ($F = 1.12$, $p = .336$), while the corresponding results for aggression were also nonsignificant at pretest ($F = 0.632$, $p = .725$), posttest ($F = 1.42$, $p = .241$), and follow-up ($F = 1.18$, $p = .321$). These findings indicated that the principal assumptions required for repeated-measures analysis were adequately met, with Greenhouse–Geisser-adjusted estimates used where sphericity was not supported.

Table 2*Repeated-Measures Analysis of Variance for Anxiety and Aggression*

Dependent Variable	Source	SS	df	MS	F	p	Partial η^2
Anxiety	Group	404.29	1	404.29	7.73	.005	.309
Anxiety	Time	316.24	2	158.12	62.70	< .001	.620
Anxiety	Time $\times$ Group	312.68	2	156.34	61.90	< .001	.618
Aggression	Group	65.40	1	65.40	4.95	.036	.150
Aggression	Time	14.18	1.60†	6.09	3.41	.042	.134
Aggression	Time $\times$ Group	34.87	1.60†	19.93	10.61	< .001	.342

The repeated-measures analysis presented in Table 2 demonstrated statistically significant treatment-related changes in both primary outcomes. For anxiety, there was a significant between-group effect, $F(1, 28) = 7.73$, $p = .005$, partial $\eta^2 = .309$, indicating an overall difference in anxiety scores between the active tDCS and sham-control groups across the study period. More importantly, the main effect of time was statistically significant, $F(2, 56) = 62.70$, $p < .001$, partial $\eta^2 = .620$, and the time $\times$ group interaction was also highly significant, $F(2, 56) = 61.90$, $p < .001$, partial $\eta^2 = .618$. The substantial interaction effect indicates that the trajectory of anxiety scores across pretest, posttest, and follow-up differed considerably between the two groups. Inspection of the descriptive means showed that this interaction resulted from a pronounced reduction in anxiety following active tDCS, whereas anxiety remained comparatively stable in the sham-control group. For

aggression, a statistically significant overall difference was also observed between the two groups, $F(1, 28) = 4.95$, $p = .036$, partial $\eta^2 = .150$. Using the Greenhouse–Geisser-adjusted results, the effect of time was significant, $F = 3.41$, $p = .042$, partial $\eta^2 = .134$, and, critically, the time $\times$ group interaction was statistically significant, $F = 10.61$, $p < .001$, partial $\eta^2 = .342$. Therefore, the pattern of aggression over time differed significantly according to treatment condition. The marked decline in aggression in the experimental group, together with the relative stability of scores in the sham-control group, supports the effectiveness of active tDCS in reducing aggressive behavior. The significant interaction effects for both outcomes provide the strongest evidence that changes over time were associated with receipt of active tDCS rather than merely reflecting repeated measurement or the passage of time.

Table 3*Bonferroni-Adjusted Pairwise Comparisons Across Measurement Occasions*

Outcome	Pairwise Comparison	Mean Difference	SE	Adjusted p
Anxiety	Pretest vs. Posttest	4.580	0.575	< .001
Anxiety	Posttest vs. Follow-up	0.289	0.626	1.000
Anxiety	Pretest vs. Follow-up	4.290	0.614	< .001
Aggression	Pretest vs. Posttest	0.899	0.267	.003
Aggression	Posttest vs. Follow-up	0.345	0.634	.859
Aggression	Pretest vs. Follow-up	0.720	0.358	.001

Bonferroni-adjusted pairwise comparisons were conducted to determine where the significant temporal differences occurred. For anxiety, a statistically significant difference was found between the pretest and posttest measurements, with an adjusted mean difference of 4.580 ($SE = 0.575$, $p < .001$), demonstrating a significant reduction following the intervention period. The difference between pretest and the one-month follow-up was likewise significant, with a mean difference of 4.290 ($SE = 0.614$, $p < .001$), indicating that the reduction in anxiety remained

evident one month after completion of treatment. In contrast, the difference between posttest and follow-up was not statistically significant, with a mean difference of 0.289 ($SE = 0.626$, $p = 1.000$), suggesting that the improvement achieved immediately after active tDCS was maintained during the follow-up period rather than substantially reversing. A similar pattern emerged for aggression. The pretest-to-posttest comparison was statistically significant, with a mean difference of 0.899 ($SE = 0.267$, $p = .003$), and the pretest-to-follow-up difference was also statistically

significant, with a mean difference of 0.720 ($SE = 0.358$, $p = .001$). By contrast, aggression did not differ significantly between posttest and follow-up, mean difference = 0.345, $SE = 0.634$, $p = .859$. Taken together with the descriptive trajectories and significant time $\times$ group effects, these comparisons indicate that active tDCS produced significant reductions in anxiety and aggression and that the observed therapeutic improvements were maintained through the one-month follow-up assessment.

4. Discussion

The present study investigated the effectiveness of transcranial direct current stimulation (tDCS) in reducing anxiety and aggression among 6- to 10-year-old boys with high-functioning autism spectrum disorder. The findings showed a clear intervention-related pattern for both outcomes. At baseline, the experimental and sham-control groups demonstrated highly similar mean scores for anxiety and aggression, indicating that the groups were broadly comparable before treatment. Following the tDCS intervention, however, the experimental group showed a substantial decline in anxiety and aggression, whereas the sham-control group remained relatively stable across the same period. Repeated-measures analysis further demonstrated statistically significant effects of time and, more importantly, significant time $\times$ group interactions for both anxiety and aggression. These interaction effects indicate that the trajectory of change over the three measurement occasions differed between the two groups and that the reductions observed in the experimental group could not be attributed solely to the passage of time or repeated assessment. In addition, Bonferroni-adjusted pairwise comparisons showed significant differences between pretest and posttest and between pretest and follow-up for both outcomes, while the differences between posttest and follow-up were nonsignificant. This pattern suggests that the therapeutic gains achieved after active stimulation were maintained during the one-month follow-up period. Taken together, the results support the effectiveness of repeated prefrontal tDCS in reducing anxiety and aggressive behavior in young boys with high-functioning ASD.

The significant reduction in anxiety observed in the experimental group is consistent with a growing body of research indicating that tDCS can influence affective regulation and anxiety-related processes. Previous studies have shown that prefrontal stimulation may reduce anxiety symptoms or modify cognitive processes closely linked to

anxiety, particularly when stimulation is directed toward cortical regions involved in executive control and regulation of negative affect. For example, tDCS has been associated with reductions in anxiety and depressive symptoms in clinical populations, including individuals with major depressive disorder and substance-related conditions (Akbari, 2018; Narimani et al., 2017). Similarly, Garcia and colleagues discussed the potential of tDCS as an intervention for anxiety and associated cognitive deficits, emphasizing that modulation of prefrontal neural systems may affect maladaptive information processing and emotional regulation (Garcia et al., 2020). Neuroimaging findings have also suggested that tDCS-related clinical improvements may coincide with measurable alterations in brain function in individuals experiencing anxiety-related symptoms (Wu et al., 2022). The current findings therefore extend earlier evidence by showing that repeated tDCS may also be beneficial for anxiety symptoms in a pediatric ASD population.

The present anxiety findings are particularly meaningful given the distinctive nature of anxiety in autism. Anxiety in autistic children may be intensified by uncertainty, heightened arousal, sensory sensitivity, atypical interoceptive processing, and difficulty regulating emotionally salient experiences. Research has demonstrated that anxiety in ASD is associated with both neurobiological and psychological mechanisms. Differences involving the amygdala have been linked to anxiety symptoms in autism, highlighting the contribution of neural circuits involved in emotional salience and threat detection (Herrington et al., 2017). More recent work has further emphasized the role of interoception, uncertainty, and subjective bodily experience in autistic anxiety (Kiera, 2025). Likewise, school-related anxiety in autistic children appears to emerge from the interaction of multiple child-level and contextual factors rather than from a single source (Fisher et al., 2026). The reduction in anxiety observed in the present study may therefore reflect improved top-down modulation of these emotionally reactive systems through stimulation of the prefrontal cortex. By increasing functional regulation in cortical networks responsible for inhibition, appraisal, and attentional control, tDCS may have reduced the intensity or persistence of anxiety-related responses in the experimental group.

The targeting of the dorsolateral prefrontal cortex provides a plausible neurocognitive explanation for this finding. The DLPFC plays an important role in executive control, attentional regulation, cognitive reappraisal,

inhibition of maladaptive responses, and modulation of subcortical emotional systems. Experimental evidence indicates that stimulation of the left DLPFC can influence psychophysiological responses during anticipation and reception of emotionally relevant feedback, suggesting that tDCS may alter the processing of affectively salient information (Allaert et al., 2020). This mechanism is especially relevant to children with ASD, who may have difficulty regulating anticipatory distress or disengaging from emotionally activating stimuli. The current findings are also compatible with autism-specific tDCS research. Zemestani and colleagues reported that prefrontal tDCS could improve emotion regulation and broader emotional-behavioral functioning in children with autism (Zemestani et al., 2022). Shamsi Halasu and colleagues similarly demonstrated beneficial effects of tDCS on executive functions in children with ASD (Shamsi Halasu et al., 2023). Although those studies did not examine exactly the same outcome configuration as the present research, they support the broader interpretation that modulation of prefrontal systems may improve regulatory processes that are clinically relevant to anxiety.

At the same time, the anxiety findings should be interpreted within the broader literature showing that tDCS effects are state-dependent and may vary according to baseline characteristics and task context. Gibson and colleagues found that baseline anxiety influenced attentional functioning and tDCS-mediated learning, suggesting that individual emotional state may moderate stimulation response (Gibson et al., 2021). Clarke and colleagues also reported that under certain conditions tDCS could increase anxiety reactivity during intentional worry (Clarke et al., 2020). These findings do not contradict the present results; rather, they demonstrate that the effects of tDCS are not universally anxiolytic and depend on stimulation parameters, cortical target, cognitive context, and participant characteristics. In the current study, repeated sessions targeting the prefrontal cortex in a structured therapeutic setting may have created conditions under which the regulatory effects of stimulation predominated. The age of participants and the relative neuroplasticity of the developing brain may also have contributed to responsiveness, although this possibility requires further investigation.

The second major finding was that tDCS significantly reduced aggression in the experimental group. Aggression decreased markedly from pretest to posttest and remained substantially lower at the one-month follow-up, whereas the

sham-control group showed little change. The significant time $\times$ group interaction indicates that the reduction in aggression was associated with the active intervention rather than simply reflecting repeated testing or natural fluctuation. This result is consistent with neurostimulation research suggesting that prefrontal tDCS can affect aggression-related processes. Sergiou and colleagues showed that stimulation targeting prefrontal regulatory regions reduced reactive aggression and altered electrophysiological responses in a randomized controlled setting (Sergiou et al., 2020). Smits and colleagues likewise reported that tDCS combined with inhibitory-control training influenced aggression alongside anxiety-related symptoms (Smits et al., 2021). These findings support the idea that aggression can be modified through neuromodulation of neural circuits responsible for inhibitory control and regulation of emotionally driven behavior.

This interpretation is especially relevant in autism, where aggression may emerge from the interaction of emotional dysregulation, low frustration tolerance, impaired inhibitory control, and heightened physiological arousal. Aggression in individuals with high-functioning autism remains clinically significant and may include reactive, impulsive, or risk-related behaviors even when general cognitive ability is relatively preserved (Moise et al., 2025). Research has also suggested that autistic traits may be related to aggressive behavior through indirect psychological pathways, reinforcing the idea that aggression in autism should not be regarded merely as deliberate behavioral misconduct (Tan et al., 2024). Instead, aggressive responses may arise when regulatory systems are insufficient to manage distress, frustration, or perceived threat. In such circumstances, enhancement of prefrontal inhibitory mechanisms through tDCS may reduce the likelihood that intense emotional activation is translated into overt aggressive behavior.

The improvement in aggression may also be explained in relation to executive control. Prefrontal cortical systems are critically involved in response inhibition, behavioral monitoring, decision-making, and suppression of prepotent impulses. Research in pediatric populations has shown that tDCS can influence executive functions such as working memory and response inhibition (Fattahi Andebil et al., 2018). Improvements in these processes may indirectly reduce aggressive behavior by helping children pause, regulate, and inhibit immediate reactive responses. Autism-specific findings demonstrating improvement in executive functioning after tDCS are therefore particularly relevant (Shamsi Halasu et al., 2023). The present study extends this

line of evidence by suggesting that such neurocognitive improvements may translate into observable behavioral reductions in aggression. The findings are also compatible with broader evidence showing that tDCS can alter prosocial and socially relevant decision processes, although the magnitude and direction of such effects vary by stimulation site and protocol (Yuan et al., 2021). Together, these findings support a model in which prefrontal tDCS strengthens regulatory control over emotionally driven or impulsive aggressive responses.

The maintenance of reduced anxiety and aggression at follow-up is another important finding. For both outcomes, posttest and follow-up scores did not differ significantly, while pretest scores remained significantly higher than follow-up scores. This pattern suggests that the effects of the intervention did not disappear immediately after stimulation ended. Sustained effects are compatible with the proposed neuroplastic mechanisms of repeated tDCS, in which cumulative stimulation may induce changes that extend beyond the period of direct current application. Follow-up research in other psychiatric conditions has shown that tDCS effects can persist beyond acute treatment periods (Aparicio et al., 2019). Although the follow-up interval in the present study was only one month, the stability of gains suggests that repeated stimulation may produce more durable regulatory changes than a single-session intervention. This is clinically meaningful because temporary symptom reduction would have limited practical value in children with chronic neurodevelopmental conditions.

The combined reduction of anxiety and aggression may also reflect the functional overlap between these two domains. Anxiety and aggression can reinforce one another, especially in children who have difficulty regulating arousal. High anxiety can increase irritability, vigilance, behavioral defensiveness, and low frustration tolerance, while recurrent aggressive episodes may generate additional stress and anticipatory distress. The concurrent decline in both variables after tDCS therefore suggests that the intervention may have influenced a common regulatory mechanism rather than acting independently on two unrelated symptoms. This interpretation is supported by studies showing that tDCS can influence both anxiety-related and aggression-related outcomes within the same regulatory framework (Smits et al., 2021). It is also consistent with evidence that family emotional processes and child behavioral problems are interconnected in ASD (Lin et al., 2023). By modulating prefrontal inhibitory control and

emotional regulation, tDCS may reduce both internalizing and externalizing manifestations of dysregulation.

The findings also have relevance in light of recent work emphasizing the broader burden of anxiety and aggression in autism. Anxiety in ASD can contribute to avoidance, distress, functional impairment, and difficulty adapting to daily demands (Dell'Osso, 2025; Fisher et al., 2026). Aggression can interfere with treatment participation, family routines, educational functioning, and safety (Moise et al., 2025). Moreover, the emotional and behavioral difficulties of autistic children may be associated with increased psychological strain among parents and caregivers (Tezcan et al., 2025; Yan & Abdullah, 2025). Therefore, interventions that reduce these symptoms may have benefits that extend beyond the child, potentially improving treatment engagement and reducing family burden. The present findings add to a growing body of evidence suggesting that noninvasive brain stimulation may serve as a useful adjunct to conventional interventions in carefully selected pediatric ASD populations.

5. Conclusion

Nevertheless, the present results should not be interpreted as evidence that tDCS is uniformly effective for all children with ASD. Studies of stimulation in autistic and non-autistic populations have demonstrated substantial variability in treatment response. Padrón and colleagues found that multisession anodal stimulation could influence cognitive processes in individuals with autistic traits (Padrón et al., 2021), whereas other work has highlighted the importance of baseline emotional and cognitive characteristics in determining responsiveness to tDCS (Gibson et al., 2021). Similarly, studies involving clinical groups outside autism have shown that tDCS effects depend on stimulation intensity, montage, treatment duration, cortical target, and individual neurobiological differences (Garcia et al., 2020; Wu et al., 2022). The current results therefore support the potential effectiveness of tDCS, but they also reinforce the need for individualized treatment planning and further research to determine which children are most likely to benefit.

The present study has several limitations that should be considered when interpreting the findings. The sample size was relatively small and included only 30 participants, which limits statistical power and reduces the extent to which the findings can be generalized to the broader population of children with ASD. In addition, all participants

were boys aged 6–10 years with high-functioning ASD, so the findings cannot automatically be generalized to girls, adolescents, children with lower intellectual functioning, or individuals with more severe forms of autism. The study was conducted in treatment and rehabilitation centers in Tehran, which may also limit generalizability to children from other cultural, socioeconomic, or clinical settings. The follow-up period was limited to one month, preventing conclusions about the long-term durability of the observed effects. Anxiety and aggression were assessed primarily through parent-report instruments, which may introduce expectancy effects, reporting bias, or shared-method variance. Although sham stimulation was used, complete verification of blinding effectiveness was not reported. In addition, neurophysiological measures were not included, so the study cannot directly determine which neural mechanisms accounted for the observed behavioral improvements.

Future studies should replicate these findings using larger, multisite samples and should include both boys and girls across a wider age range and broader levels of autism severity. Randomized controlled trials with stronger allocation concealment and formal assessment of blinding success would further strengthen causal inference. Longer follow-up periods, such as three, six, and twelve months, are recommended to determine the persistence of treatment effects. Future research should also compare different stimulation montages, current intensities, session frequencies, and numbers of treatment sessions to identify the most effective and tolerable protocol for children with ASD. Incorporating objective neurophysiological and neurocognitive measures, including EEG, functional neuroimaging, response inhibition tasks, and physiological indices of arousal, could clarify the mechanisms underlying reductions in anxiety and aggression. Future investigations could also examine potential moderators of treatment response, such as age, baseline symptom severity, medication status, cognitive functioning, emotional regulation capacity, and sensory sensitivity. Comparative studies combining tDCS with psychological or behavioral interventions may also determine whether multimodal approaches produce larger or more durable improvements than either intervention alone.

In clinical practice, tDCS may be considered as a complementary intervention for children with high-functioning ASD who present with clinically significant anxiety and aggression, provided that it is administered by appropriately trained professionals under established pediatric safety protocols. Careful screening for neurological

contraindications, medication changes, skin conditions, and other safety concerns should precede treatment. Clinicians should monitor children during each session for discomfort, headache, dizziness, skin irritation, or behavioral distress and should document adverse events systematically. tDCS should not replace established psychological, behavioral, educational, or medical treatments but may be integrated into a broader individualized rehabilitation plan. Parents should receive clear information about the expected benefits, limitations, and possible transient adverse effects of stimulation and should be encouraged to maintain stable treatment routines during the intervention period. Repeated outcome assessment should be used to determine whether clinically meaningful reductions in anxiety and aggression occur and whether gains are maintained after treatment completion.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

References

- Akbari, B. (2018). Effectiveness of Transcranial Direct Current Stimulation (tDCS) on Rumination, Negative Automatic Thoughts, and Psychological Symptoms (Anxiety and Depression) in Patients with Major Depression. *Iranian Journal of Psychology and Behavioral Sciences*(15), 52-58.
- Allaert, J., Raedt, R. D., Sánchez-López, Á., Baeken, C., & Vanderhasselt, M. A. (2020). Mind the Social Feedback: Effects of tDCS Applied to the Left DLPFC on Psychophysiological Responses During the Anticipation and Reception of Social Evaluations. *Social Cognitive and Affective Neuroscience*, 17(1), 131-141. <https://doi.org/10.1093/scan/nsaa066>
- Aparicio, L. V., Rosa, V., Razza, L. M., Sampaio-Junior, B., Borriore, L., Valiengo, L., & Gattaz, W. F. (2019). Transcranial direct current stimulation (tDCS) for preventing major depressive disorder relapse: Results of a 6-month follow-up. *Depression and Anxiety*, 36(3), 262-268. <https://doi.org/10.1002/da.22878>
- Clarke, P. J. F., Spryan, B. F., Hirsch, C. R., Meeten, F., & Notebaert, L. (2020). tDCS increases anxiety reactivity to intentional worry. *Journal of psychiatric research*, 120, 34-39.
- Dell'Osso, L. (2025). Autism spectrum disorder, social anxiety and obsessive-compulsive disorders: beyond the comorbidity. *BMC psychiatry*, 25(1). <https://doi.org/10.1186/s12888-024-06340-8>
- Fattahi Andebil, A., Saberi, H., & kazemi kavaki, a. (2018). Effectiveness of Cognitive behavioral group Play therapy and Transcranial Direct Current Stimulation on Executive Function of Working Memory And Response Inhibition of Children with Attention Deficit- Hyperactivity Disorder. *Neuropsychology*, 4(14), 73-90. <https://doi.org/10.30473/clpsy.2019.42393.1369>
- Fisher, E., Rob, P., MacLennan, K., Mullally, S., Rodgers, J., & Tzemou, E. (2026). School Anxiety Experienced by Autistic Children: A Systematic Review of Contributing Factors. *School Mental Health*. <https://doi.org/10.1007/s12310-026-09852-8>
- Garcia, S., Nalven, M., Ault, A., & Eskenazi, M. A. (2020). tDCS as a treatment for anxiety and related cognitive deficits. *International Journal of Psychophysiology*, 158, 172-177. <https://doi.org/10.1016/j.ijpsycho.2020.10.006>
- Gibson, B. C., Heinrich, M., Mullins, T. S., Yu, A. B., Hansberger, J. T., & Clark, V. P. (2021). Baseline Differences in Anxiety Affect Attention and tDCS-Mediated Learning. *Frontiers in human neuroscience*, 15. <https://doi.org/10.3389/fnhum.2021.541369>
- Herrington, J. D., Maddox, B. B., Kerns, C. M., Rump, K., Worley, J. A., Bush, J. C., McVey, A. J., Schultz, R. T., & Miller, J. S. (2017). Amygdala Volume Differences in Autism Spectrum Disorder Are Related to Anxiety. *Journal of Autism and Developmental Disorders*, 47(12), 3682-3691. <https://doi.org/10.1007/s10803-017-3206-1>
- Inci, R., & Saglam, M. (2025). Investigation of the effect of interactive art activity program on repetitive behaviors, social skills and parents' emotions in children with autism spectrum disorder. *Advances in Autism*, 11(1), 5-18. <https://doi.org/10.1108/AIA-06-2024-0041>
- Jafari, R., & Yousefi, R. (2023). The effectiveness of social cognition training based on theory of mind on stereotyped behaviors, social interaction, and empathy in children with autism spectrum disorder. *Tabriz University Psychology Journal*, 18(1), 129-146. https://psychologyj.tabrizu.ac.ir/article_16944_30ea8f2366e42cca4192d031c63379c2.pdf
- Jahedi Delivand, S., Tarkhan, M., Ahadhi, M., & Qodsi, P. (2024). The effectiveness of transcranial direct current stimulation (tDCS) treatment on the quality of life and anxiety of children with attention-deficit/hyperactivity disorder (ADHD). *Scientific Research Journal of School and Virtual Learning*, 12(3), 29-38. https://etl.journals.pnu.ac.ir/article_11639.html?lang=en
- Jouy, L. (2025). The Effect of Resilience Skills Training on Improving Social Interactions in Children with Autism Spectrum Disorder. Neyshabur.
- Karna, W., & Stefaniuk, I. (2024). The Influence of Peer Relationships on the Social Development of Children with Autism Spectrum Disorder. *Iranian Journal of Neurodevelopmental Disorders*, 2(4), 10-18. <https://doi.org/10.61838/kman.jndd.2.4.2>
- Kiera, A. (2025). Experiences of Interoception and Anxiety in Autistic Adolescents: A Reflexive Thematic Analysis. *Autism*. <https://doi.org/10.1177/13623613251314595>
- Lin, X., Lin, L., Wang, X., Li, X., Cao, M., & Jing, J. (2023). Association between Mothers' Emotional Problems and Autistic Children's Behavioral Problems: The Moderating Effect of Parenting Style. *International journal of environmental research and public health*, 20(5).
- Moise, M., Andrei, L. E., Mihăilescu, I., Buică, A., & Rad, F. (2025). Aggression and Risk Behaviors in a Group of Adolescents With High-Functioning Autism. *Children*, 12(7), 852. <https://doi.org/10.3390/children12070852>
- Narimani, M., Pouresmali, A., alizadeh goradel, j., & Mowlai, M. (2017). The effect of tranecranial Direct Current Stimulation (tDCS) on reduction of craving, depression and anxiety in students with tramadol abuse: Preliminary study [Research]. *Research on Addiction*, 10(40), 87-102. <http://etiadpajohi.ir/article-1-1115-en.html>
- Padrón, I., García-Marco, E., Moreno, I., Birba, A., Silvestri, V., León, I., Álvarez, C. J., López, J., & Vega, M. d. (2021). Multisession Anodal tDCS on the Right Temporo-Parietal Junction Improves Mentalizing Processes in Adults With Autistic Traits. *Brain Sciences*, 12(1), 30. <https://doi.org/10.3390/brainsci12010030>
- Reddy, P., & J. A. (2023). Diagnosis of Autism in Children Using Deep Learning Techniques by Analyzing Facial Features. *Engineering Proceedings*, 59(1).
- Sergiou, C. S., Santarnecchi, E., Romanella, S. M., Wieser, M. J., Franken, I. H. A., Rassin, E., & Josanne, D. M. v. D. (2020). tDCS Targeting the Ventromedial Prefrontal Cortex Reduces Reactive Aggression and Modulates Electrophysiological Responses: A HD-tDCS/EEG Randomized Controlled Trial in a Forensic Population. <https://doi.org/10.31234/osf.io/cjgdt>
- Shamsi Halasu, M., Tabatabaei, S. M., & Azmodeh, M. (2023). Comparing the Effectiveness of Transcranial Direct Current Stimulation (tDCS) and Cognitive Rehabilitation on Executive Functions in Children with Autism Spectrum Disorders. *Scientific Journal of Pajouhan*, 21(2), 113-121. <https://doi.org/10.61186/psj.21.2.113>
- Smits, F., Geuze, E., Schutter, D. J., Honk, J. v., & Gladwin, T. E. (2021). Effects of tDCS During Inhibitory Control Training on Performance and PTSD, Aggression and Anxiety Symptoms: A Randomized-Controlled Trial in a Military Sample. *Psychological medicine*, 52(16), 3964-3974. <https://doi.org/10.1017/s0033291721000817>
- Soqandi, K., Rezaei, M., & Amirabadizadeh, A. (2024). Effectiveness of Anodal Transcranial Direct Current Stimulation (tDCS) on Happiness and Symptoms of Military-Related Post-Traumatic Stress Disorder (PTSD). Seventh International Conference on Psychology, Educational Sciences, and Social Studies, Hamedan.

- Tan, C., Song, H., Ma, S., Liu, X., & Zhao, Y. (2024). Autistic Traits and Aggressive Behavior in Chinese College Students: A Serial Mediation Model and the Gender Difference. *Psychology research and behavior management*, 1385-1397. <https://doi.org/10.2147/PRBM.S451028>
- Tezcan, M. E., Çaltıner, Ş. N. İ., Demirel, H. R., Korucu, B. N., Şen, B., & Ekici, F. (2025). The Relationship Between Executive Functioning and Burnout, Depressive, Anxiety and Broad Autism Phenotype Symptoms in Parents of Children With Autism Spectrum Disorder. *Online Türk Sağlık Bilimleri Dergisi*, 10(2), 170-177. <https://doi.org/10.26453/otjhs.1672755>
- Wu, Y., Tang, L., Shi, X., Zhou, Z., Li, Y., & Shan, C. (2022). Effects of tDCS on Depression and Comorbid Generalized Anxiety Disorder: A Brain Function Imaging Case Report. *Frontiers in Neurology*, 13. <https://doi.org/10.3389/fneur.2022.879339>
- Yan, Y., & Abdullah, E. B. (2025). Clinical Interventions for Depression and Anxiety in Mothers of Children With Autism Spectrum Disorder in China. *Ls*, 1(3), 1-27. <https://doi.org/10.71204/srdzv858>
- Yuan, B., Tolomeo, S., Yang, C., Wang, Y., & Yu, R. (2021). tDCS Effect on Prosocial Behavior: A Meta-Analytic Review. *Social Cognitive and Affective Neuroscience*, 17(1), 26-42. <https://doi.org/10.1093/scan/nsab067>
- Zemestani, M., Hoseinpanahi, O., Salehinejad, M. A., & Nitsche, M. A. (2022). The Impact of Prefrontal Transcranial Direct Current Stimulation (<scp>tDCS</Scp>) on Theory of Mind, Emotion Regulation and Emotional-behavioral Functions in Children With Autism Disorder: A Randomized, Sham-controlled, and Parallel-group Study. *Autism Research*, 15(10), 1985-2003. <https://doi.org/10.1002/aur.2803>
- Zhai, J., Li, X., Zhou, Y., Fan, L., Xia, W., Wang, X., Li, Y., Hou, M., Wang, J., & Wu, L. (2023). Correlation and Predictive Ability of Sensory Characteristics and Social Interaction in Children With Autism Spectrum Disorder. *Frontiers in Psychiatry*, 14. <https://doi.org/10.3389/fpsyt.2023.1056051>
- Zoghipaydar, M., Hasany Khosh, Z., Yar Mohammadi Wasel, M., & Mohagheghi, H. (2022). Comparing of Transcranial Direct Current Stimulation (TDCS) and Methadone Maintenance Treatment(MMT) on Emotion Regulation, Distress Tolerance and Decreased Craving in People with Substance Use Disorder(SUD). *Neuropsychology*, 7(27), 95-109. <https://doi.org/10.30473/clpsy.2021.59493.1606>