Case report

Effects of transcranial direct current stimulation combined with speech therapy in two children with autism spectrum disorder: a clinical case series

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ABSTRACT | BACKGROUND: Transcranial direct current stimulation (tDCS) has shown promise as an adjunctive therapy for neurological and developmental conditions, including autism spectrum disorder (ASD). **OBJECTIVE**: To describe the preliminary effects of a tDCS protocol combined with traditional speech therapy in two children with ASD. **METHODS:** This case series involved two male children, aged 4-5 years, diagnosed with ASD. A total of 30 tDCS sessions (1mA, 30 minutes each) were delivered over 10 weeks (CP5–Fp2 montage), combined with language-focused speech therapy. Parents completed the Social Responsiveness Scale (SRS-2) before and after the intervention. **RESULTS:** Quantitative improvements were observed in social cognition, communication, and motivation, alongside reductions in restrictive behaviors. Qualitative gains included enhanced verbal intention, vocabulary, sentence construction, and emotional regulation. **CONCLUSION:** These findings support the feasibility and potential therapeutic benefit of combining tDCS with speech therapy in young children with ASD, warranting further investigation in controlled trials.

KEYWORDS: Autism Spectrum Disorder. Transcranial Direct Current Stimulation. Speech Therapy. Neuromodulation. Case Series.

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1. Introduction

Neurodevelopmental disorders are a group of chronic conditions that affect brain function from the first years of life and impair motor, cognitive, social and communication skills[1]. Among these disorders, autism spectrum disorder (ASD) has shown an increasing prevalence and significant functional impact that challenges conventional therapeutic approaches. According to 2020 data from the CDC, the estimated prevalence of ASD is approximately 1 in 36 children in the United States[2]. Worldwide, PAHO/WHO estimates that approximately 1 in 160 children are affected by ASD. In Brazil, although there is no official data, it is estimated that about 1% of the population is on the autism spectrum[3].

The main manifestations of ASD include impairments in social communication, repetitive and stereotyped behavior patterns and significant deficits in receptive, expressive and pragmatic language[1]. Many people with ASD have marked difficulties in these language areas. Although interventions such as traditional speech therapy offer benefits, some patients show limited progress over time. A systematic review has shown that interventions based on verbal communication and augmentative and alternative communication (AAC) have limited evidence of sustained efficacy in minimally verbal children with ASD[4].

In this context, non-invasive neuromodulation techniques such as transcranial direct current stimulation (tDCS) have proven to be promising tools in the field of neurofunctional rehabilitation. tDCS works by modulating cortical excitability in a polarity-dependent manner and can induce permanent changes in synaptic neuroplasticity. There is evidence that stimulation of brain regions involved in language and social cognition can enhance the effects of behavioral and educational interventions[5–7].

Although ASD is one of the most studied disorders in the field of pediatric neuromodulation, most tDCS studies still use isolated protocols with a limited number of sessions, without systematically combining stimulation with specific therapeutic interventions. A recent systematic review highlighted that despite the growing number of randomized clinical trials with children and adolescents with ASD, combined approaches with behavioral or educational therapies remain rare in the literature[8].

Some studies have begun to highlight the potential of tDCS in combination with cognitive-linguistic training and home-based rehabilitation strategies[9], suggesting that integration with task-oriented therapies may enhance stimulation effects through task-dependent mechanisms. However, there are few studies that combine tDCS with speech therapy in intensive, clinically detailed protocols. Thus, this case report contributes to this emerging field by uniquely describing the longitudinal link between tDCS and structured speech therapy, focusing on communicative and social clinical outcomes.

1.1 Objective

To describe the preliminary effects of a tDCS protocol combined with traditional speech therapy in two children with ASD.

2. Method

2.1 About the patient

This case report involves two male children who were between 4 and 5 years old at the start of the intervention. Both were diagnosed with autism spectrum disorder (ASD) by a multidisciplinary team consisting of a pediatric neurologist, a speech-language pathologist, and an occupational therapist. The patients attended private schools and participated in extracurricular activities such as music lessons and sports. They had no known medical comorbidities or family history of ASD and were the first diagnosed cases in their respective families.

The main complaints were significant deficits in functional language, which impaired verbal communication, social reciprocity and the development of both formal (academic and

conceptual) and informal (social and practical) learning. Both children were already being treated by speech therapists and occupational therapists using conventional approaches. However, they showed limited progress and clinical outcomes that fell short of expectations, which led to their inclusion in an integrated protocol that included non-invasive neuromodulation (tDCS) in combination with speech therapy.

Patient 1 showed marked deficits in social perception and motivation and had considerable difficulties in engaging in communication. His spoken language was predominantly monosyllabic in Portuguese, while he showed a preference for English in spontaneous contexts. He showed low frustration tolerance, difficulty following instructions and resistance to imitation activities, including symbolic gestures and language-related motor acts.

Patient 2 showed a hyperlexic profile with intense interest in letters and numbers, along with immediate and delayed echolalia, verbal stereotypies (e.g. crying) and frequent episodes of emotional dysregulation in response to frustration, often manifesting as aggression towards others. His difficulties with functional communication and pragmatic language use significantly limited his social interactions.

This case report was approved by the Research Ethics Committee of São João de Deus Hospital — Fundação Geraldo Corrêa (Divinópolis — MG), under ethics approval number 7.461.447 (CAAE: 86847124.6.0000.5130). The legal guardians of both patients signed the Free and Informed Consent Form (FICF), authorizing their participation and the anonymous disclosure of clinical data, in accordance with national and international ethical guidelines for research with human participants.

2.2 Therapeutic intervention

Both children underwent a combined protocol of tDCS and conventional speech therapy aimed at improving therapeutic gains in functional language and communicative skills. The tDCS protocol consisted of 30 sessions of 30 minutes each with a current strength of 1 mA, conducted over a period of 10 weeks. The stimulation was performed with the anode at CP5 (left temporal region) and the cathode at Fp2 (right frontal-orbital region), according to the international 10–20 EEG system. The schedule followed a progressive structure: five sessions per week in the first two weeks, three sessions per week from the third to the fifth week and two sessions per week from the sixth to the tenth week.

In parallel with neuromodulation, the children attended speech therapy sessions focusing on the development of receptive, expressive and pragmatic language. The sessions were conducted by a professional who already had experience with ASD interventions. The focus was on contextualized verbal activities, emphasizing communicative intent, vocabulary expansion, functional language use, and frustration tolerance training.

In addition to the in-clinic sessions, caregivers were instructed to repeat some of the strategies used at home, supported by therapeutic materials provided for home use. This approach aimed to promote generalization of therapeutic gains and reinforce continuity of stimulation in the natural environment. Throughout the protocol, no changes were made to the stimulation parameters or the structure of the speech therapy intervention. All sessions were supervised by trained clinicians, and participants were continuously monitored for potential adverse effects, such as erythema, tingling, itching, or headache. Any adverse event was to be recorded and reported to the research ethics committee.

2.3 Assessment tools

Caregivers completed the Social Responsiveness Scale — Second Edition (SRS) before and after the intervention. The SRS-2 is a standardized, validated questionnaire designed to measure the severity of social impairment associated with ASD across five domains: social awareness, social cognition, social communication, social motivation, and restricted repetitive behaviors. Standardized T-scores (mean = 50; SD =10) were calculated, and reductions in T-scores indicated clinical improvement.

2.4 Clinical findings

Before the intervention, both children presented with significant impairments in functional communication, social reciprocity, and emotional regulation, consistent with diagnosis of ASD. Their developmental and behavioral profiles, though distinct, shared overlapping features of language delay and limited pragmatic use of speech.

Patient 1 exhibited severe deficits in social awareness and motivation, with marked difficulty initiating or sustaining verbal exchanges. His expressive language consisted of single words or short phrases, often accompanied by limited eye contact and reduced use of gestures. He showed low tolerance to frustration, resistance to imitation-based activities, and a tendency to withdraw during structured social interactions. Caregivers also reported inconsistent verbal comprehension, particularly for complex or abstract instructions, and a preference for solitary play.

Patient 2 demonstrated a hyperlexic profile, characterized by an early and intense interest in letters and numbers, combined with limited functional language use. Speech was frequently dominated by immediate and delayed echolalia, with repetitive verbalizations and stereotyped phrases. Episodes of emotional dysregulation were common, often triggered by changes in routine or communicative challenges, leading to agitation or aggression. Despite his strong memory and cognitive curiosity, his pragmatic language and reciprocal communication were notably impaired, restricting their ability to engage in meaningful social exchanges.

Both cases were considered clinically stable, without comorbid neurological or psychiatric conditions, and had been receiving conventional speech and occupational therapy prior to inclusion in the combined tDCS protocol. Their baseline profiles thus provided a consistent framework for assessing the effects of the intervention on social communication, functional language, and behavioral regulation.

3. Results

The effects of tDCS in combination with speech therapy were analyzed using standardized measures and qualitative observations by caregivers and the clinical team. The results indicate consistent improvements in behavioral, social and communicative domains in both patients.

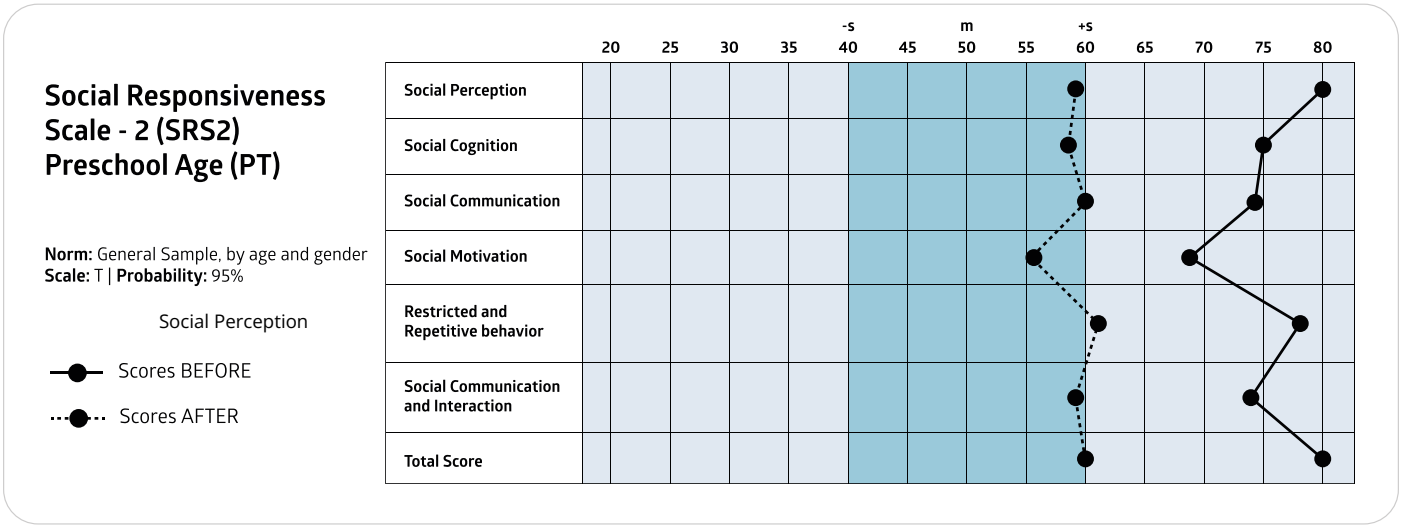
Throughout the 30 tDCS sessions conducted with each participant, no adverse events or clinically significant discomfort were reported. Both children demonstrated excellent tolerability to the stimulation protocol. Patient 1 occasionally reported a mild tingling sensation during the initial minutes of stimulation, which resolved spontaneously within a few seconds, without requiring interruption of the session. Patient 2 exhibited no sensory discomfort or behavioral reactions related to the stimulation procedure. No erythema, headache, or irritability was observed following any of the sessions.

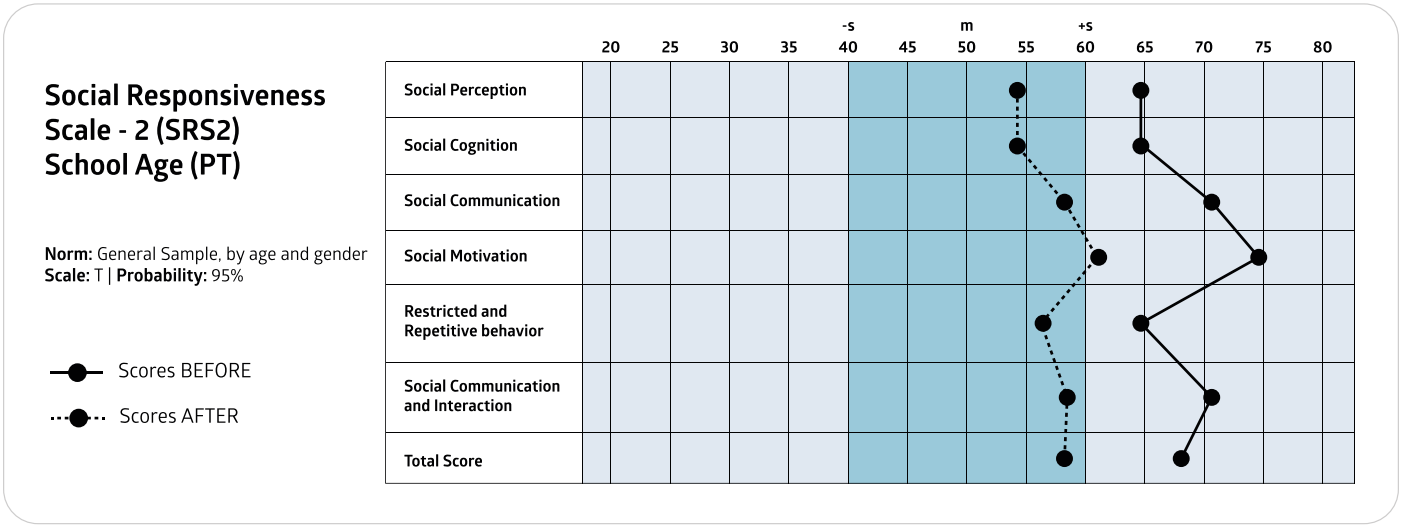
a) Quantitative results

The Social Responsiveness Scale — 2 (SRS-2) was administered to guardians before and after the intervention protocol. Standardized T-scores (mean = 50; standard deviation = 10) were analyzed across five subdomains: social perception, social cognition, social communication, social motivation, and restricted and repetitive behaviors, in addition to the total score.

As shown in Figure 1, both children demonstrated a decrease in total scores and all subscales analyzed, indicating an overall improvement in social responsiveness and a decrease in traits associated with ASD. The most pronounced changes were observed in the social motivation and restricted and repetitive behaviors subscales, indicating greater interpersonal engagement and increased behavioral flexibility after the intervention.

Figure 1. Development of SRS-2 scores by subdomain before and after the intervention. Panel A: Patient 1 — Preschool age; Panel B: Patient 2 — School age





Source: the authors (2025).

b) Qualitative results

Clinical observations and caregiver reports showed significant progress in the areas of functional language, adaptive behavior, and emotional regulation.

Patient 1 showed improvements in communicative intent, expansion of expressive vocabulary, use of complex sentences, faster verbal responses, and greater clarity in expressing thoughts and feelings. Frustration tolerance and the ability to wait one's turn during social interactions also improved.

In Patient 2, caregivers reported the absence of immediate and delayed echolalia episodes, more appropriate and functional vocabulary use in social contexts, more spontaneous verbal initiative, less aggressive behavior, and greater emotional stability. Improvements in social reciprocity and behavioral flexibility were also evident from caregiver reports and clinical observations.

c) The caregivers' perspective

At the end of the protocol, the children's caregivers shared how they perceived the impact of the intervention on family dynamics and the quality of social interactions. The following excerpts illustrate their subjective experiences:

> *"My son opened up! He came out of his shell and started interacting with people and the world around him. He expressed his voice, his thoughts and his wishes. Today he is active and happy. All this happened after tDCS. Sometimes I am even surprised by his behavior and language — he is now spontaneous and proactive in communicating and interacting with us."*
> *(Parents of patient 1, 2025)*

> *"From a very young age, he impressed us with reading words, even without us teaching him. But a good dialog or meaningful interaction was almost impossible as he only repeated what he heard and got very upset when he was contradicted. After tDCS, everything changed. We are now able to relate to him and communicate with him efficiently and calmly."*
> *(Parent of patient 2, 2025)*

These narratives support the clinical and psychometric findings, showing not only an improvement in communicative and behavioral skills but also a significant change in the daily lives of the affected families. The convergence between objective data, clinical observations and the caregivers' perspective underpins the relevance of the combined approach of tDCS and speech therapy.

4. Discussion

The results of this clinical case series suggest that tDCS in combination with traditional speech therapy can achieve clinically relevant effects in children with ASD, particularly in the areas of functional language, social communication, and behavioral flexibility. Results obtained with the SRS-2 showed consistent improvements across multiple subscales, particularly in the areas of social cognition, social motivation, and restricted and repetitive behaviors — areas generally recognized as central to the diagnostic profile of ASD[1]. These findings are consistent with the literature suggesting tDCS as a complementary tool capable of modulating cortical excitability and facilitating neuroplasticity processes, especially when combined with specific therapies such as language interventions[10].

Recent studies support this perspective. Kang et al. (2025) showed that tDCS could modulate brain complexity and effective connectivity in children with ASD, accompanied by measurable improvements in behavior[11]. Similarly, Chen et al. (2024) showed that multi-session tDCS combined with cognitive training resulted in significant gains in inhibitory control and sustained attention, suggesting that the effects of brain stimulation are enhanced when combined with structured and repetitive interventions[12].

In the present study, caregivers reported notable improvements in children's language use, social engagement, and emotion regulation that extended beyond the objective assessment outcomes, highlighting the functional relevance of the intervention. The convergence of quantitative measures, systematic clinical observations and caregiver-reported outcomes reinforces the hypothesis that tDCS may serve as a facilitator of neuroplasticity when implemented within structured therapeutic frameworks such as speech therapy.

In addition to the observed clinical benefits, this study is characterized by the innovative design of the intervention protocol, which includes a total of 30 tDCS sessions spread over two phases: an initial intensive phase (with five sessions per week during the first two weeks), followed by a gradual tapering until the tenth week. This structure was inspired by the staged models widely used in neuropsychological rehabilitation and psychopharmacology, which aim to reinforce the induction of neuroplasticity through intensive repetition and to consolidate therapeutic gains with gradual maintenance.

In the field of neuromodulation, this type of approach remains under-researched in pediatric ASD populations. Most clinical studies of tDCS use short protocols of up to 10 consecutive sessions, often without linkage to specific tasks. However, recent evidence suggests that systematic repetition of tDCS over several weeks — especially in combination with structured behavioral or cognitive interventions — may increase the efficacy and durability of therapeutic outcomes[10,12].

The adoption of a 30-session protocol was also grounded in robust safety evidence from the literature. Systematic reviews involving hundreds of sham-controlled studies in adults, including protocols with up to 30 consecutive sessions at 2mA, have not identified an increased incidence of adverse events with higher cumulative charge, with side effects generally being mild and transient, such as erythema and paraesthesia[13]. Complementary reviews focusing on pediatric populations describe tolerability patterns similar to those observed in adults when conventional parameters are used (≤ 2 mA, 20 min), and recent cohorts comprising over one thousand sessions in children and adolescents further support the feasibility and safety of repeated-session regimens when delivered under rigorous clinical monitoring[14,15]. These data provided the rationale for implementing the present extended protocol, combined with continuous monitoring, in which no significant adverse events were observed in the cases reported.

The CP5–Fp2 montage was selected to deliver anodal stimulation over the left posterior perisylvian cortex, approximated by CP5 in the 10–20 EEG system, with the return electrode over the right prefrontal pole (Fp2). This target includes Wernicke's area — critically involved in language comprehension, phonological processing, and lexical access — and adjacent temporo-parietal regions that integrate auditory–linguistic information[16]. Evidence from neurostimulation studies supports this choice: Sparing et al. demonstrated that anodal tDCS over the left posterior perisylvian area, encompassing Wernicke's area (Brodmann area 22), reduced naming latencies in healthy individuals, whereas stimulation of the right homologous area had no effect[17]. Floel et al. found that anodal tDCS over Wernicke's area significantly accelerated learning speed and improved accuracy during acquisition of a novel lexicon, outperforming cathodal and sham stimulation and without influencing mood or general reaction times[18]. Similarly, Fiori et al. reported shorter naming latencies during word retrieval tasks with anodal stimulation over Wernicke's area, indicating its specific involvement in activating phonological representations in the late stages of lexical access[19]. Collectively, these findings provide a robust neurofunctional rationale for targeting the left temporo-parietal junction with anodal tDCS in the present protocol.

Although the CP5–Fp2 configuration primarily targets the left posterior perisylvian region, the placement of the return electrode over the right prefrontal pole (Fp2) also engages prefrontal circuits associated with higher-order cognitive and social processes. The prefrontal cortex — particularly its orbitofrontal and medial sectors — plays a crucial role in pragmatic language use, executive control of communication, and Theory of Mind (ToM)[20]. These regions support self-monitoring, perspective-taking, and the integration of social cues during interpersonal exchanges, all of which are domains frequently impaired in autism spectrum disorder (ASD)[21]. Therefore, the present montage may have contributed not only to linguistic comprehension via temporo-parietal stimulation but also to the modulation of socio-cognitive and emotional networks through prefrontal engagement. In line with recent neuroimaging evidence, autism is increasingly understood as a disorder involving large-scale network dysconnectivity rather than focal cortical dysfunction. Studies indicate that communication and social cognition in ASD rely on distributed frontoparietal and subcortical mechanisms, encompassing the amygdala, anterior cingulate cortex, and basal ganglia[22,23]. Future tDCS studies should therefore consider montage designs capable of engaging this extended network to enhance modulation of social, linguistic, and affective behaviors in this population.

Although only two cases are described, this study was structured as a case series, with standardized intervention parameters, consistent therapeutic goals, and pre- and post-intervention assessments. As such, it provides initial insights into the feasibility and potential clinical effects of combining tDCS with speech therapy in children with ASD.

However, several limitations should be acknowledged. First, the small sample size prevents generalization of the findings and limits statistical inference. Second, the absence of a control or sham group precludes conclusions about the specific contribution of tDCS to the observed improvements. Third, the use of caregiver-reported outcomes may be influenced by subjective expectations or placebo effects. A further limitation of this study is the absence of standardized language assessment tools beyond the SRS-2. Future studies should incorporate detailed speech and language evaluations to better characterize specific linguistic domains affected

by the intervention and to complement caregiver-based and qualitative findings. Finally, the lack of longitudinal follow-up impedes evaluation of the durability of the observed clinical gains.

Although limited by its small sample size and the absence of a control group, this study provides valuable preliminary evidence supporting the feasibility of multimodal neuromodulation in pediatric ASD. It represents an important first step toward the development of clinical trials with robust, randomized, and controlled designs, guided by innovative longitudinal protocols. The findings encourage future investigations to refine stimulation parameters — such as session frequency, cumulative dose, and total duration — to identify an optimal therapeutic balance for pediatric populations. Beyond its exploratory nature, this case series opens the discussion for rethinking tDCS intervention strategies in ASD, emphasizing the need to move from isolated short-term protocols toward integrated, task-linked, and developmentally informed approaches to neuromodulation.

5. Conclusion

This case series provides preliminary evidence that tDCS, when combined with structured speech therapy, may promote clinically relevant gains in functional language, social communication, and behavioral flexibility in children with ASD. The innovative 30-session protocol, grounded in established safety parameters and supported by a neurofunctional montage rationale, was well tolerated and free of significant adverse events. These findings support further controlled studies to explore the efficacy, optimal dosing, and long-term effects of multimodal interventions integrating neuromodulation in pediatric ASD.

Authors' contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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