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Comparison of the Effects of Sensory–Motor Integration and Cognitive Restructuring on Executive Functions and Social Skills in Individuals with Autism Spectrum Disorder

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A B S T R A C T

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder characterized by impairments in social interaction and communication, as well as restricted and repetitive patterns of behavior. Children with this disorder commonly experience substantial difficulties in executive functions and social skills, which may adversely affect their academic and social adjustment. Therefore, identifying and implementing effective interventions to improve these abilities is of particular importance. In recent years, interventions based on sensory–motor integration and cognitive restructuring have received increasing attention as potentially effective approaches for improving cognitive and social functioning in children with autism spectrum disorder. The present study aimed to examine the effectiveness and durability of sensory–motor integration and cognitive restructuring interventions in improving executive functions and social skills among children with autism spectrum disorder. This study employed a quasi-experimental design with pretest, posttest, and two-month follow-up assessments and a control group. The statistical population consisted of students aged 7–12 years with autism spectrum disorder in Kerman, Iran. From this population, 45 participants were selected using purposive sampling and randomly assigned to three groups of 15 participants: the sensory–motor integration group, the cognitive restructuring group, and the control group. The research instruments included the Behavior Rating Inventory of Executive Function (BRIEF) and the Gresham and Elliott Social Skills Rating System (Teacher Form). Data were analyzed using repeated-measures analysis of variance. The results indicated that the effect of time was significant for executive functions ($F = 13.90$, $p < .01$) and social skills ($F = 9.90$, $p < .01$). In addition, the time × group interaction effect was significant for executive functions ($F = 9.90$, $p < .01$, $\eta^2 = .54$) and social skills ($F = 9.90$, $p < .01$, $\eta^2 = .44$). Post hoc comparisons showed that both interventions resulted in significant improvements in executive functions and social skills compared with the control group ($p < .05$). Furthermore, the sensory–motor integration intervention was more effective than cognitive restructuring, and these effects were maintained at the follow-up assessment (executive functions: $F = 17.87$, $p < .01$, $\eta^2 = .45$; social skills: $F = 12.57$, $p < .01$, $\eta^2 = .37$). Therefore, both interventions are suggested to use to improve executive functions and social skills in individuals with autism spectrum disorder while sensory-motor integration is more effective than cognitive restructuring intervention.

Keywords: *autism spectrum disorder, sensory–motor integration, cognitive restructuring, executive functions, social skills*

1. Introduction

Autism spectrum disorder (ASD) is a heterogeneous neurodevelopmental condition characterized primarily by persistent difficulties in social communication and social interaction, accompanied by restricted, repetitive patterns of behavior, interests, or activities. Contemporary conceptualizations of autism emphasize considerable variation in symptom presentation, developmental trajectories, cognitive profiles, adaptive functioning, and support needs, indicating that ASD cannot be adequately understood as a unitary behavioral condition (Happé & Frith, 2020; Niehaus, 2021). These differences are particularly evident during childhood, when demands for behavioral regulation, social reciprocity, communication, academic participation, and independent functioning become increasingly complex. Although social-communication difficulties and restricted or repetitive behaviors constitute the core diagnostic domains of ASD, many children also experience substantial challenges in sensory processing, motor control, executive functioning, emotional self-regulation, and social competence. Such associated difficulties may interact with one another and intensify limitations in educational participation, peer relationships, daily functioning, and adaptation to changing environmental demands. Consequently, contemporary intervention research has increasingly moved beyond the reduction of isolated symptoms toward approaches designed to improve the underlying cognitive, sensory–motor, and social processes that support adaptive functioning.

Executive functions constitute one of the most important cognitive domains associated with successful behavioral adaptation in childhood. Executive functioning refers to a set of higher-order cognitive and self-regulatory processes that enable individuals to initiate and organize goal-directed behavior, inhibit inappropriate responses, shift flexibly between activities or mental sets, maintain and manipulate information in working memory, monitor performance, plan actions, and regulate emotional responses. These processes are essential for learning, classroom behavior, problem solving, social interaction, and independent functioning. Evidence indicates that executive functions are closely associated with children's ability to respond effectively to academic and environmental demands, and difficulties in these processes can interfere with planning, attention regulation, behavioral control, and task completion (Deng et al., 2020; Sosic-Vasic et al., 2017). Executive functions are also influenced by children's opportunities for active engagement in structured physical and cognitively demanding activities; for example, participation in open-skilled and relatively intensive sport activities has been associated with executive functioning and academic performance in school-age children (Becker et al., 2018). Thus, executive functions are not merely abstract cognitive abilities but constitute a functional system that is continually engaged in children's everyday behavior.

Executive dysfunction is particularly relevant to ASD. Meta-analytic evidence has demonstrated broad executive-function impairments among individuals with autism spectrum disorder, although the magnitude and specific pattern of deficits may vary across executive domains and individual characteristics (Demetriou et al., 2018). Difficulties may appear in inhibition, cognitive flexibility, planning, working memory, initiation, and monitoring, all of which can make it more difficult for children with ASD to cope with transitions, adapt to novel situations, organize behavior, suppress repetitive responses, and integrate multiple sources of information. Executive-function difficulties may also contribute indirectly to social and educational problems because successful social behavior frequently requires rapid interpretation of contextual information, inhibition of inappropriate responses, flexible modification of behavior, and maintenance of social goals in working memory. Accordingly, improving executive functioning may produce benefits that extend beyond cognitive task performance to classroom adaptation, interpersonal behavior, and participation in daily activities.

Social skills represent another major developmental concern in children with ASD. Social functioning depends on a complex set of behavioral, emotional, cognitive, and communicative abilities, including initiating and maintaining interactions, understanding interpersonal cues, cooperating with others, expressing needs appropriately, regulating emotional reactions, exercising self-control, and adapting behavior to social contexts. During childhood, social-emotional competence and empathy develop through repeated interpersonal experiences and are closely related to children's ability to understand both their own emotions and those of others (Denham et al., 2023). Social interaction skills can also be strengthened through systematic training and repeated opportunities to practice effective interpersonal responses (Talvio et al., 2015). For children with ASD, however, difficulties with social reciprocity, interpretation of social information, behavioral flexibility, and communication may restrict participation in peer interactions and reduce opportunities for acquiring and

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consolidating age-appropriate social behaviors. Consequently, interventions aimed at improving social competence have become an important component of psychological, educational, and rehabilitation services for this population.

Previous intervention research has demonstrated that social skills in children with ASD are amenable to structured treatment. Play-based approaches, for example, have been associated with improvements in social skills and reductions in stereotyped behaviors among boys with ASD (Dadashzadeh et al., 2020). Similarly, cooperative-game interventions have been developed specifically to strengthen social skills by creating structured opportunities for collaboration, reciprocal interaction, rule following, and shared activity among children with autism spectrum disorder (Fathabadi et al., 2020). These findings are important because they suggest that social functioning can improve when interventions provide repeated, purposeful, and developmentally appropriate opportunities for active engagement. At the same time, the multidimensional nature of ASD suggests that interventions targeting social behavior directly may not fully address sensory, motor, and cognitive processes that contribute to children's social performance. This has increased interest in interventions that influence more fundamental regulatory systems, including sensory–motor integration.

Sensory processing difficulties are frequently observed in children with ASD and may involve atypical responses to tactile, vestibular, proprioceptive, auditory, or visual stimulation. Sensory integration refers to the nervous system's capacity to receive, organize, interpret, and coordinate information from different sensory systems in order to generate adaptive responses. Effective sensory processing supports postural control, body awareness, attention, motor planning, emotional regulation, and purposeful interaction with the environment (Khodabakhshi, 2020). Importantly, sensory functioning may also be related to higher-order cognition. Research examining sensory processing and executive functioning has demonstrated associations between sensory-processing characteristics and executive abilities, suggesting that the quality of sensory regulation may influence children's capacity to organize and control behavior (Adams et al., 2015). A similar relationship has been documented specifically among students with autism disorder, in whom sensory-processing patterns have been associated with executive-function performance (Asadi Gandmani et al., 2016). These findings provide an important theoretical basis for considering sensory–motor intervention as a potentially relevant approach to improving not only sensory responses but also cognitive and behavioral regulation.

Sensory–motor functioning depends on coordinated integration of sensory input with motor planning and execution. Proprioception, for example, contributes to the perception of body position and movement and plays a fundamental role in motor control, postural regulation, and the accurate performance of goal-directed actions (Han et al., 2023). Contemporary motor-control frameworks similarly emphasize that movement emerges from interactions among the individual, the task, and the environment and depends on the effective integration of sensory information with motor responses (Shumway-Cook & Woollacott, 2022). Sensory–motor integration therefore involves more than the performance of physical exercises; it requires continuous coordination between sensory feedback, central processing, motor planning, and behavioral adjustment. Experimental research on complex motor learning further supports the biological importance of sensory–motor integration and indicates that individual neurobiological characteristics may influence the efficiency of sensory–motor learning processes (Deveci et al., 2020). Such findings are especially relevant to ASD because atypical sensorimotor behavior has increasingly been recognized as an important feature of the broader autism phenotype.

Recent research has provided additional evidence of distinctive sensorimotor characteristics among individuals with ASD. Sensorimotor differences have been observed not only in individuals diagnosed with ASD but also, to some extent, among unaffected biological parents, suggesting that aspects of sensorimotor functioning may be related to broader neurodevelopmental characteristics associated with autism (Bojanek et al., 2025). From an intervention perspective, these findings strengthen the rationale for directly addressing sensorimotor functioning rather than regarding motor and sensory difficulties as secondary or peripheral symptoms. Structured sensory–motor activities may create opportunities to improve body awareness, balance, coordination, motor planning, response organization, and regulation of arousal, which may subsequently facilitate engagement in cognitive and social tasks.

A growing body of intervention research supports the potential value of sensory integration and sensory–motor approaches for children with ASD. Sensory integration-based training has been shown to improve sensory status among children with high-functioning autism spectrum

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disorder (Behrouzmanesh et al., 2023), while sensory–motor integration exercises have also been reported to reduce autism-related symptoms (Sadeghian et al., 2017). Other studies have similarly reported reductions in symptoms following sensory integration-based interventions (Shokri, 2019) and improvements when sensory–motor exercises were implemented with parental assistance (Hassanzadeh, 2021). Collectively, these findings indicate that structured exposure to sensory and motor experiences may promote more adaptive regulation of sensory input and more organized behavioral responses.

Sensory–motor interventions may also have implications for executive functioning. Sensory–motor integration therapy has been reported to improve executive functions and reduce stereotyped behaviors in children with autism (Hayatinia & Kashkooli, 2022). Evidence from children with developmental coordination difficulties similarly suggests that sensory–motor integration activities can strengthen attention and working memory, both of which are closely related to executive functioning (Shahbazi & Heyrani, 2018). Sensory–motor interventions have also been investigated in other neurodevelopmental populations, with reports suggesting potential benefits of sensory–motor integration training for attentional and self-regulatory functioning (Shin-Siung Jung & Simon Jung, 2020). Furthermore, research with students with learning disabilities has demonstrated that sensory–motor integration therapy can influence academic-related difficulties such as reading performance, supporting the proposition that improvements in sensory–motor organization may transfer to higher-order learning processes (Sadati Firouzabadi & Abbasi, 2018). These findings support the possibility that sensory–motor training may improve executive functions by enhancing attentional regulation, sensory modulation, action planning, and coordinated responses to environmental demands.

There is also evidence that sensory–motor approaches may contribute to social development in ASD. A sensory–motor intervention program has been associated with improvements in social profile and social interest among children with high-functioning autism (Rezaei & Bakhtiari, 2019). Sensorimotor exercises have likewise been reported to improve communication and social interaction among children with autism spectrum disorder (Garcia & Torres, 2021), while sensorimotor intervention has been associated with reductions in stereotyped behavior that may otherwise interfere with adaptive interaction and participation (Nguyen et al., 2021). More recent findings have further strengthened this line of research. Sensory integration-based sports training has demonstrated beneficial effects on both motor and social skill development in children with ASD (Wen & Wu, 2025), suggesting that interventions combining sensory regulation with active motor participation may simultaneously influence physical and interpersonal functioning. Similarly, preliminary findings from sensorimotor room training indicate improvements in sensory and motor abilities among children with autism spectrum disorders, further highlighting the potential clinical utility of structured multimodal sensorimotor environments (Savarese et al., 2025). Taken together, these studies suggest that sensory–motor integration may affect social functioning indirectly through improvements in sensory regulation, motor competence, attentional availability, and behavioral organization, as well as directly through increased engagement in structured interactive activities.

Despite the growing emphasis on sensory–motor interventions, cognitive approaches remain equally important because many behavioral difficulties in ASD are influenced by the ways in which individuals interpret situations, regulate internal responses, and guide behavior through cognitive strategies. Cognitive restructuring is a central component of cognitive-behavioral approaches and involves identifying maladaptive, inaccurate, or unhelpful thoughts and replacing them with more adaptive interpretations. In children, cognitive restructuring is often combined with relaxation, emotion identification, problem solving, self-instruction, and positive self-talk. These strategies may be particularly relevant to executive functioning because they encourage deliberate inhibition of automatic responses, monitoring of internal states, evaluation of alternative interpretations, planning, and controlled behavioral selection. Research specifically examining cognitive restructuring training in children with ASD has suggested that such training can improve executive functioning, supporting its potential role in strengthening self-regulatory and cognitive-control processes (Harris & Thompson, 2023).

The theoretical mechanisms underlying cognitive restructuring and sensory–motor integration differ substantially. Cognitive restructuring primarily targets top-down processes by teaching children to recognize thoughts and emotions, reconsider interpretations, use self-directed language, solve problems systematically, and regulate behavior through consciously applied strategies. Sensory–motor integration, in contrast, emphasizes bottom-up regulation by organizing sensory input, improving motor

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responses, and facilitating more adaptive interactions between the nervous system and environmental demands. Both pathways may ultimately influence executive and social functioning, but they may do so through different mechanisms. A child who becomes better able to regulate vestibular and proprioceptive input may demonstrate improved attention, postural stability, behavioral organization, and readiness for interaction, whereas a child who acquires cognitive restructuring skills may become better able to inhibit ineffective responses, reinterpret challenging situations, and generate alternative solutions. This distinction makes direct comparison of the two approaches theoretically and clinically valuable.

A comparative examination is particularly important because existing studies have often evaluated these interventions independently, used different outcome variables, or focused on immediate post-intervention effects rather than the maintenance of gains over time. The available evidence supports relationships between sensory processing and executive functioning (Adams et al., 2015; Asadi Gandmani et al., 2016), indicates that sensory–motor intervention may improve autism-related sensory, behavioral, cognitive, and social outcomes (Behrouzmanesh et al., 2023; Garcia & Torres, 2021; Hayatinia & Kashkooli, 2022; Wen & Wu, 2025), and suggests that cognitive restructuring may strengthen executive control (Harris & Thompson, 2023). Nevertheless, it remains necessary to determine whether these approaches differ in their relative effects when administered within the same research design, to the same clinical population, and with executive functions and social skills assessed concurrently. Evaluating durability is also essential, because statistically significant post-intervention improvement does not necessarily indicate that treatment effects persist after structured sessions have ended.

The practical relevance of this comparison is considerable for professionals working in psychological, educational, occupational therapy, and rehabilitation settings. Intervention time and clinical resources are often limited, and children with ASD frequently require support across several developmental domains simultaneously. An intervention capable of improving both executive functioning and social skills while maintaining these effects over time may offer substantial advantages for educational adjustment and everyday participation. Moreover, identifying whether a predominantly sensory–motor intervention or a predominantly cognitive intervention produces stronger effects could help clinicians and educators make more evidence-informed decisions about intervention planning. Given the central importance of executive control for adaptive behavior and the fundamental role of social skills in children's interpersonal and educational functioning, clarifying the comparative effectiveness of these two intervention approaches may contribute to more targeted and developmentally responsive programs for children with ASD.

Accordingly, the present study aimed to compare the effectiveness and two-month durability of sensory–motor integration and cognitive restructuring interventions on executive functions and social skills in children with autism spectrum disorder.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a quasi-experimental design with pretest, posttest, and two-month follow-up assessments, including two experimental groups and one control group. Cognitive restructuring and sensory–motor integration interventions were considered the independent variables, whereas executive functions and social skills were regarded as the dependent variables. Following the baseline assessment, eligible participants were randomly assigned to one of the three study groups. The two experimental groups subsequently received their respective interventions, while the control group received no research-related intervention during the study period. Outcome measures were administered again immediately after completion of the interventions and at a two-month follow-up to examine both the immediate effectiveness and the durability of the intervention effects. The statistical population consisted of students aged 7–12 years with autism spectrum disorder who attended specialized autism education and rehabilitation centers in Kerman, Iran, during the 2024–2025 academic year. A total of 45 eligible students were selected through purposive sampling and subsequently randomly assigned to three groups of 15 participants each: the cognitive restructuring group, the sensory–motor integration group, and the control group. The inclusion criteria were a confirmed diagnosis of autism spectrum disorder by a qualified specialist, age between 7 and 12 years, absence of significant sensory or physical disabilities or multiple disabilities, sufficient physical capacity to participate in the intervention activities, and the ability to understand and follow basic instructions. The exclusion criteria included severe behavioral problems that interfered with participation, occurrence of seizures, use of medications

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considered likely to substantially affect the study variables, and repeated absence from intervention sessions. After the necessary administrative permissions had been obtained, the aims, procedures, potential requirements, and voluntary nature of participation were explained to the participants' parents, and written informed consent was obtained before enrollment. Teachers completed the study measures at the pretest, posttest, and follow-up assessments. Participants and their parents were assured that all personal information would remain confidential, that findings would be reported anonymously, and that participation could be discontinued at any stage without penalty.

2.2. Measures

Behavior Rating Inventory of Executive Function. Executive functioning was assessed using the Behavior Rating Inventory of Executive Function (BRIEF), developed by Gioia, Isquith, Guy, and Kenworthy (2000). The BRIEF is a standardized behavioral rating instrument designed to assess executive functioning as manifested in children's everyday environments and includes forms that can be completed by parents and teachers. In the present study, the 86-item Teacher Form was administered because teachers were considered capable of evaluating participants' executive behaviors within structured educational and social settings. The inventory assesses several domains of executive functioning, including inhibition, shifting or cognitive flexibility, emotional control, working memory, planning and organization, monitoring, and initiation. Items are rated on a three-point response scale according to the frequency with which each behavior is observed. The instrument provides a broad behavioral assessment of children's ability to regulate behavior, manage cognitive demands, organize goal-directed activity, maintain information in working memory, and adapt flexibly to changing environmental demands. In the present sample, internal consistency was satisfactory, with a Cronbach's alpha coefficient of .85, indicating adequate reliability for the assessment of executive functioning across the three measurement occasions.

Social Skills Rating System. Social skills were assessed using the Social Skills Rating System developed by Gresham and Elliott (1990). The instrument includes 48 items and is available in different versions for completion by parents, teachers, and students. The Teacher Form was used in the present study to obtain a consistent external evaluation of children's social functioning in educational and interpersonal contexts. The social skills component evaluates important dimensions of adaptive social behavior, including cooperation, assertion, and self-control. Cooperation reflects behaviors such as following directions, appropriately assisting others, and complying with classroom expectations; assertion refers to socially appropriate initiation of interactions and expression of needs or ideas; and self-control concerns the ability to regulate behavioral and emotional responses during interpersonal situations. Items are rated on a three-point frequency scale ranging from never to sometimes and often. Previous psychometric investigations have supported the reliability and applicability of the scale for assessing social functioning in children, and the Teacher Form was therefore considered appropriate for evaluating changes in participants' social skills across the pretest, posttest, and follow-up stages.

2.3. Interventions

Cognitive Restructuring Intervention. Participants assigned to the first experimental group received a cognitive restructuring program based on Meichenbaum's cognitive-behavioral approach. The intervention consisted of six 45-minute sessions designed to increase awareness of maladaptive thoughts and emotional responses and to strengthen adaptive cognitive and self-regulatory strategies. The first session focused on establishing rapport with the participants, familiarizing them with the intervention setting, explaining the structure of the sessions, and introducing the general relationship between thoughts, emotions, and behavior in a developmentally appropriate manner. The second session was devoted to relaxation training, through which participants practiced basic strategies for reducing physiological arousal and increasing behavioral and attentional control. During the third session, participants were trained to identify thoughts and emotions associated with challenging situations and were introduced to cognitive restructuring techniques intended to replace maladaptive or unhelpful interpretations with more realistic and adaptive alternatives. The fourth session focused on problem-solving skills, including identifying a problem, considering possible responses, evaluating alternatives, and selecting an appropriate behavioral solution. The fifth session emphasized self-instruction and positive self-talk, with participants practicing the use of simple internal verbal cues to guide behavior, regulate emotional responses, remain focused on tasks, and manage challenging interpersonal situations. The sixth and final session involved reviewing

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and consolidating the skills acquired during the intervention, practicing their combined use, and reinforcing their application to situations encountered in daily, educational, and social contexts.

Sensory–Motor Integration Intervention. Participants assigned to the second experimental group received a sensory–motor integration program consisting of six 45-minute sessions. The intervention was designed to provide structured sensory and motor experiences with particular emphasis on vestibular, proprioceptive, and tactile stimulation and was intended to improve motor coordination, balance, motor planning, body awareness, and regulation of sensory responses. Each session followed a general sequence consisting of warm-up activities, structured sensory–motor exercises, and cool-down activities. The first session focused on familiarization with the intervention environment and introduced basic motor and balance exercises to prepare participants for progressively more complex activities. The second session emphasized vestibular stimulation and balance training through activities requiring controlled changes in body position, postural adjustment, and maintenance of equilibrium. The third session concentrated on eye–hand coordination and goal-directed targeting activities intended to enhance visual–motor integration, attentional control, and coordinated movement. The fourth session focused on proprioceptive stimulation and resistance-based activities that required participants to generate, control, and adjust muscular force while processing information regarding body position and movement. The fifth session integrated balance and motor coordination exercises, requiring participants to combine previously practiced sensory and motor skills in more complex movement sequences. The sixth session incorporated combined sensory–motor exercises and emphasized consolidation of the skills acquired throughout the program. Across sessions, activities were structured to provide repeated, organized sensory input while encouraging adaptive motor responses and active engagement.

2.4. Data Analysis

Data analysis was conducted using both descriptive and inferential statistical procedures. At the descriptive level, means and standard deviations were calculated for executive function and social skills scores separately for each study group at the pretest, posttest, and two-month follow-up assessments. Before conducting the main inferential analyses, the relevant statistical assumptions were examined, including normality of the distribution of scores, homogeneity of variances across groups, and the assumption of sphericity for repeated measurements. Given the three-group design and the assessment of the dependent variables at three measurement occasions, repeated-measures analysis of variance was employed to evaluate changes in executive functions and social skills over time. The analysis examined the within-subject effect of time, the between-subject effect of group, and, most importantly, the time × group interaction to determine whether patterns of change across the pretest, posttest, and follow-up assessments differed among the cognitive restructuring, sensory–motor integration, and control groups. Where statistically significant overall or interaction effects were identified, appropriate follow-up comparisons were used to determine the location and direction of differences among the study groups and assessment occasions. Effect sizes were also considered when interpreting the magnitude of intervention effects. All statistical tests were conducted using a two-tailed significance criterion of $p < .05$.

3. Findings and Results

Data from 45 participants were included in the final analyses. Of the participants, 26 (57.78%) were girls and 19 (42.22%) were boys. Regarding age distribution, 20 participants were aged 7–8 years, 13 were aged 9–10 years, and 12 were aged 11–12 years. Descriptive statistics were calculated for executive functions and social skills across the pretest, posttest, and two-month follow-up assessments in the sensory–motor integration, cognitive restructuring, and control groups. As presented in Table 1, the descriptive results provide an initial indication of changes in both outcome variables over time and allow comparison of the patterns of change across the three study groups.

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Table 1

Descriptive Statistics for Executive Functions and Social Skills Across the Three Measurement Times

Variable	Group	Measurement	*M*	*SD*
Executive functions	Sensory–motor integration	Pretest	41.57	6.98
Executive functions	Sensory–motor integration	Posttest	49.98	8.26
Executive functions	Sensory–motor integration	Follow-up	50.04	8.37
Executive functions	Cognitive restructuring	Pretest	42.25	6.67
Executive functions	Cognitive restructuring	Posttest	47.92	8.98
Executive functions	Cognitive restructuring	Follow-up	47.44	8.26
Executive functions	Control	Pretest	40.59	6.16
Executive functions	Control	Posttest	41.15	6.59
Executive functions	Control	Follow-up	40.98	5.65
Social skills	Sensory–motor integration	Pretest	23.05	3.97
Social skills	Sensory–motor integration	Posttest	29.12	5.65
Social skills	Sensory–motor integration	Follow-up	28.55	5.15
Social skills	Cognitive restructuring	Pretest	22.47	3.66
Social skills	Cognitive restructuring	Posttest	27.17	5.28
Social skills	Cognitive restructuring	Follow-up	27.02	5.42
Social skills	Control	Pretest	22.84	3.42
Social skills	Control	Posttest	22.97	3.88
Social skills	Control	Follow-up	23.05	3.82

As shown in Table 1, the mean executive function score in the sensory–motor integration group increased from 41.57 (*SD* = 6.98) at pretest to 49.98 (*SD* = 8.26) at posttest and remained at 50.04 (*SD* = 8.37) at the two-month follow-up. In the cognitive restructuring group, the mean increased from 42.25 (*SD* = 6.67) at pretest to 47.92 (*SD* = 8.98) at posttest and was 47.44 (*SD* = 8.26) at follow-up. In contrast, the control group showed only minimal changes, with means of 40.59, 41.15, and 40.98 at the three respective assessments. A similar pattern was observed for social skills. The sensory–motor integration group increased from a pretest mean of 23.05 (*SD* = 3.97) to 29.12 (*SD* = 5.65) at posttest and maintained a mean of 28.55 (*SD* = 5.15) at follow-up. The cognitive restructuring group increased from 22.47 (*SD* = 3.66) to 27.17 (*SD* = 5.28) and 27.02 (*SD* = 5.42), respectively, whereas the control group remained relatively stable across pretest (*M* = 22.84, *SD* = 3.42), posttest (*M* = 22.97, *SD* = 3.88), and follow-up (*M* = 23.05, *SD* = 3.82). Overall, the descriptive findings suggested improvement in both experimental groups, with a larger change observed in the sensory–motor integration group.

Before conducting the inferential analyses, the relevant statistical assumptions were examined. The Kolmogorov–Smirnov tests indicated no significant deviation from normality for executive function or social skills scores across the study groups and measurement occasions, with all significance values exceeding .05. The assumption of homogeneity of regression slopes was also supported because the interactions between pretest scores and group membership were nonsignificant for executive functions ($F = 0.55$, $p > .05$) and social skills ($F = 0.59$, $p > .05$). Similarly, the interactions between group membership and change from pretest to follow-up were nonsignificant for executive functions ($F = 1.12$, $p > .05$) and social skills ($F = 0.74$, $p > .05$). Levene's tests further indicated homogeneity of variances for executive functions ($F = 3.08$, $p > .05$), social skills ($F = 3.09$, $p > .05$), follow-up executive function scores ($F = 1.07$, $p > .05$), and follow-up social skills scores ($F = 1.98$, $p > .05$). Accordingly, the available assumption tests supported the use of repeated-measures analysis of variance.

Table 2

Repeated-Measures Analysis of Variance for Executive Functions and Social Skills

Dependent Variable	Effect	*F*	*p*	η^2
Executive functions	Time	13.90	< .01	.54
Executive functions	Time × Group	9.90	< .01	.44
Social skills	Time	9.90	< .01	.44

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Social skills	Time × Group	9.90	< .01	.44
Executive functions	Group effect at follow-up	17.87	< .01	.45
Social skills	Group effect at follow-up	12.57	< .01	.37

The repeated-measures analysis of variance indicated significant changes in both dependent variables across the three measurement occasions. For executive functions, the main effect of time was statistically significant, $F = 13.90$, $p < .01$, $\eta^2 = .54$, indicating that executive function scores changed significantly from pretest through posttest and follow-up. More importantly, the time × group interaction was also significant, $F = 9.90$, $p < .01$, $\eta^2 = .44$, demonstrating that the pattern of change over time differed significantly among the sensory–motor integration, cognitive restructuring, and control groups. For social skills, a significant effect of time was likewise observed, $F = 9.90$, $p < .01$, $\eta^2 = .44$, together with a significant time × group interaction, $F = 9.90$, $p < .01$, $\eta^2 = .44$. These interaction effects indicate that changes in social skills were dependent on group membership and therefore differed according to the intervention received. The overall between-group multivariate effect was also significant, Pillai's trace = .53, $F = 6.14$, $p < .01$. Examination of the follow-up data further showed that group differences remained significant two months after completion of the interventions for both executive functions, $F = 17.87$, $p < .01$, $\eta^2 = .45$, and social skills, $F = 12.57$, $p < .01$, $\eta^2 = .37$. Thus, the improvements observed following the interventions were not limited to the immediate posttest and were maintained at the follow-up assessment.

Table 3

Post Hoc Pairwise Comparisons at Posttest and Follow-up

Variable	Assessment	Group Comparison	Mean Difference	*SE*	*p*
Executive functions	Posttest	Cognitive restructuring − Sensory–motor integration	-2.06	0.72	< .05
Executive functions	Posttest	Cognitive restructuring − Control	6.77	0.64	< .05
Executive functions	Posttest	Sensory–motor integration − Control	8.83	0.83	< .05
Social skills	Posttest	Cognitive restructuring − Sensory–motor integration	-1.95	0.72	< .05
Social skills	Posttest	Cognitive restructuring − Control	4.20	0.64	< .05
Social skills	Posttest	Sensory–motor integration − Control	6.15	0.83	< .05
Executive functions	Follow-up	Cognitive restructuring − Sensory–motor integration	-2.60	0.77	< .05
Executive functions	Follow-up	Cognitive restructuring − Control	6.46	1.02	< .05
Executive functions	Follow-up	Sensory–motor integration − Control	9.06	0.32	< .05
Social skills	Follow-up	Cognitive restructuring − Sensory–motor integration	-1.53	0.64	< .05
Social skills	Follow-up	Cognitive restructuring − Control	3.97	1.12	< .05
Social skills	Follow-up	Sensory–motor integration − Control	5.53	0.52	< .05

The post hoc pairwise comparisons presented in Table 3 showed that, at posttest, both intervention groups differed significantly from the control group in executive functions and social skills ($p < .05$). For executive functions, the cognitive restructuring group scored 6.77 points higher than the control group, whereas the sensory–motor integration group scored 8.83 points higher than the control group. The significant mean difference of -2.06 between cognitive restructuring and sensory–motor integration indicated that the sensory–motor integration group achieved significantly higher executive function scores. A comparable pattern was observed for social skills: the cognitive restructuring and sensory–motor integration groups scored 4.20 and 6.15 points higher than the control group, respectively, and the sensory–motor integration group significantly outperformed the cognitive restructuring group by 1.95 points. These differences remained statistically significant at the two-month follow-up. For executive functions, the cognitive restructuring group remained 6.46 points above the control group, while the sensory–motor integration group was 9.06 points above the control group; the latter also exceeded the cognitive restructuring group by 2.60 points. For social skills, cognitive restructuring exceeded the control condition by 3.97 points and sensory–motor integration exceeded it by 5.53 points, while the sensory–motor integration group remained 1.53 points higher than the cognitive restructuring group. Collectively, these findings demonstrate that both interventions were effective in improving executive functions and social skills relative to the control condition, that the improvements persisted at the two-month follow-up, and that sensory–motor integration produced consistently greater improvements than cognitive restructuring.

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4. Discussion

The present study examined the comparative effectiveness of sensory–motor integration and cognitive restructuring interventions on executive functions and social skills in children with autism spectrum disorder (ASD), as well as the durability of intervention effects over a two-month follow-up period. The findings showed that both interventions produced significant improvements in executive functions and social skills compared with the control condition. The repeated-measures analyses demonstrated significant effects of time and significant time × group interactions for both dependent variables, indicating that changes across the pretest, posttest, and follow-up assessments differed according to the intervention received. Post hoc comparisons further showed that the sensory–motor integration group achieved significantly greater improvements than the cognitive restructuring group in both executive functions and social skills. Importantly, the gains observed in both intervention groups remained significant at the two-month follow-up, with the sensory–motor integration group continuing to demonstrate the strongest performance. These findings suggest that both interventions can be effective for improving cognitive and social functioning in children with ASD, although sensory–motor integration may exert broader or stronger effects on the outcomes assessed in the present study.

The finding that sensory–motor integration significantly improved executive functions is consistent with previous research demonstrating associations between sensory processing, motor regulation, and higher-order cognitive functioning. Hayatinia and Kashkooli reported that sensory–motor integration therapy was effective in improving executive functions and reducing stereotyped behaviors in children with autism, supporting the present finding that structured sensory–motor stimulation can contribute to better executive regulation (Hayatinia & Kashkooli, 2022). Similarly, Asadi Gandmani et al. identified significant relationships between sensory processing patterns and executive functions among students with autism disorder, indicating that atypical sensory processing may be closely associated with difficulties in executive regulation (Asadi Gandmani et al., 2016). The findings are also compatible with evidence from Adams et al., who showed that sensory processing was associated with executive functioning in preschool children, further suggesting that sensory organization and executive control are functionally interconnected rather than independent processes (Adams et al., 2015). Thus, improving the efficiency with which sensory information is registered, modulated, and integrated may facilitate cognitive processes involved in inhibition, working memory, planning, monitoring, and behavioral regulation.

A possible explanation for the improvement in executive functions following sensory–motor integration is that executive behavior depends partly on the child's ability to maintain an appropriate level of physiological and sensory regulation. When sensory input is poorly modulated, attentional resources may be diverted toward managing overstimulation, under-responsiveness, or disorganized bodily sensations, reducing the cognitive capacity available for goal-directed behavior. Sensory–motor activities that systematically engage vestibular, proprioceptive, and tactile systems may help organize arousal, postural control, body awareness, and motor responses, thereby creating more favorable conditions for executive control. Proprioceptive information, in particular, is essential for regulating movement and accurately representing the position of the body in space, while sensory feedback continuously contributes to adaptive motor control (Han et al., 2023). Contemporary models of motor control likewise emphasize the dynamic interaction among sensory information, movement planning, task demands, and environmental constraints (Shumway-Cook & Woollacott, 2022). Through repeated sensory–motor practice, children may therefore become better able to regulate attention, organize responses, inhibit ineffective actions, and adapt behavior to changing demands.

The present findings also correspond with studies showing that motor and sensory experiences can enhance attention, working memory, and broader cognitive regulation. Shahbazi and Heyrani found that sensory–motor integration activities improved attention and working memory in children with developmental coordination disorder (Shahbazi & Heyrani, 2018). Although their sample differed diagnostically from the present participants, the findings support the idea that structured sensory–motor experiences can influence cognitive systems closely related to executive functioning. Becker et al. similarly demonstrated associations between participation in open-skilled sports, exercise intensity, executive functioning, and academic achievement in school-age children, emphasizing the cognitive demands embedded within coordinated physical activity (Becker et al., 2018). Findings from sensory–motor integration training in other neurodevelopmental populations also suggest potential

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effects on attentional and self-regulatory processes (Shin-Siung Jung & Simon Jung, 2020). Collectively, these studies provide a plausible explanation for the observed executive-function gains by indicating that movement-based interventions can simultaneously engage sensory, attentional, inhibitory, and planning processes.

The significant improvement in executive functioning following cognitive restructuring was also consistent with previous evidence. Harris and Thompson reported that cognitive restructuring training improved executive functioning in children with ASD, supporting the applicability of cognitive-behavioral strategies for strengthening cognitive control in this population (Harris & Thompson, 2023). Cognitive restructuring requires the child to recognize automatic thoughts, evaluate their usefulness, generate alternatives, and intentionally modify behavioral responses. These activities recruit several executive processes simultaneously, including working memory, inhibition, cognitive flexibility, monitoring, and planning. In the present intervention, cognitive restructuring was combined with relaxation, identification of thoughts and emotions, problem-solving training, self-instruction, and positive self-talk. These components likely increased children's capacity to pause before responding, identify alternative courses of action, and use internal verbal strategies to guide behavior. Because executive deficits are common and relatively broad in ASD (Demetriou et al., 2018), interventions that explicitly teach cognitive self-regulation may provide structured compensatory strategies for weaknesses in executive control.

The improvement observed in the cognitive restructuring group may also be interpreted in relation to the developmental and environmental nature of executive functioning. Executive functions are influenced not only by neurocognitive characteristics but also by children's experiences of behavioral guidance, interpersonal interaction, and opportunities to practice self-regulation. Sosic-Vasic et al. demonstrated associations between parenting behavior and executive functioning in children and young adolescents, underscoring the importance of environmental support for the development of executive control (Sosic-Vasic et al., 2017). Similarly, problem solving and self-directed speech can provide external and internal scaffolding for executive behavior. In children with ASD, who may experience difficulties adapting spontaneously to complex social or cognitive demands, clearly structured cognitive strategies may help transform ambiguous situations into manageable sequences of actions. Thus, the effectiveness of cognitive restructuring in the present study may reflect its capacity to provide explicit, repeatable strategies that support organization and self-control.

Regarding social skills, both experimental interventions led to significant improvements compared with the control group. This result is consistent with the broader literature indicating that social functioning in children with ASD can be enhanced through structured and repeated intervention. Dadashzadeh et al. found that play therapy improved social skills and reduced stereotyped behaviors among boys with ASD (Dadashzadeh et al., 2020), while Fathabadi et al. demonstrated the effectiveness of a cooperative-games educational package in improving social skills in children with autism spectrum disorder (Fathabadi et al., 2020). These studies suggest that social deficits in ASD, although central to the disorder, are responsive to intervention when children are provided with developmentally appropriate opportunities to practice cooperation, reciprocal behavior, emotional regulation, and purposeful interaction. Social-emotional competence develops through repeated experiences involving the recognition, expression, and regulation of emotions and through progressively more complex interpersonal exchanges (Denham et al., 2023). Therefore, changes in underlying regulatory capacities may translate into observable improvements in social functioning.

The stronger effect of sensory–motor integration on social skills is particularly noteworthy and is supported by several previous studies. Rezaei and Bakhtiari reported that a sensory–motor intervention program improved social profile and social interest in children with high-functioning autism (Rezaei & Bakhtiari, 2019). Garcia and Torres likewise found that sensorimotor exercises enhanced communication and social interaction in children with ASD (Garcia & Torres, 2021). More recently, Wen and Wu showed that sensory integration-based sports training had beneficial effects on both motor and social skill development in children with autism spectrum disorder (Wen & Wu, 2025). These convergent findings support the proposition that sensory and motor regulation may play a meaningful role in children's readiness and ability to engage socially. When children are more comfortable with sensory input and better able to coordinate their movements, they may demonstrate greater availability for interpersonal attention, reciprocal play, shared activities, and classroom participation.

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One mechanism that may explain the effect of sensory–motor integration on social skills concerns reductions in behavioral disorganization and stereotyped behavior. Nguyen et al. reported that sensorimotor interventions reduced stereotyped behaviors in children with ASD (Nguyen et al., 2021), and Sadeghian et al. similarly found improvements in autism-related symptoms following sensory–motor integration exercises (Sadeghian et al., 2017). Shokri also reported reduced symptom severity after sensory integration-based treatment (Shokri, 2019). Repetitive or dysregulated behaviors can compete with opportunities for engagement and may reduce responsiveness to peers, teachers, or therapists. If sensory–motor intervention decreases the need for repetitive self-stimulation or improves regulation of sensory arousal, children may become more available for social attention and participation. This may help explain why the sensory–motor group in the present study not only improved relative to the control group but also exceeded the cognitive restructuring group in social skills.

Additional support for this interpretation comes from research demonstrating direct improvements in sensory functioning following intervention. Behrouzmanesh et al. found sensory integration-based training to be effective in improving the sensory status of children with high-functioning ASD (Behrouzmanesh et al., 2023), while Hassanzadeh reported beneficial effects of sensory–motor integration exercises implemented with parental assistance (Hassanzadeh, 2021). Savarese et al. also reported preliminary evidence that sensorimotor room training improves sensory and motor abilities in children with ASD (Savarese et al., 2025). At a broader level, Bojanek et al. documented distinctive sensorimotor behaviors in individuals with ASD and their unaffected biological parents, reinforcing the view that sensorimotor functioning may represent a meaningful dimension of the autism phenotype (Bojanek et al., 2025). These findings suggest that interventions that address sensory–motor organization may target a domain that is deeply connected to everyday adaptive functioning rather than merely improving isolated motor abilities.

The effect of cognitive restructuring on social skills can be explained through different mechanisms. Cognitive restructuring encourages children to identify thoughts and emotions, reconsider interpretations, use problem-solving strategies, and regulate responses through self-instruction. These processes may enhance social functioning because successful interpersonal behavior requires the ability to inhibit impulsive responses, recognize situational demands, consider alternative actions, and select contextually appropriate behavior. Social competence also depends on emotional awareness and self-regulation, which are central targets of cognitive-behavioral techniques. Continued training in social interaction has been shown to strengthen interpersonal competencies in educational contexts (Talvio et al., 2015). Therefore, although cognitive restructuring does not directly provide vestibular, proprioceptive, or tactile stimulation, it may improve social performance by strengthening the cognitive processes that organize behavior during social situations.

The finding that sensory–motor integration was more effective than cognitive restructuring may be related to the developmental characteristics of the study population. The participants were between 7 and 12 years of age, and children with ASD may differ substantially in language abilities, abstract reasoning, insight, and capacity to identify and modify internal cognitions. Cognitive restructuring generally requires a certain level of metacognitive and verbal capacity, whereas sensory–motor activities can often be experienced and practiced more directly. Accordingly, sensory–motor intervention may be more accessible to children who have difficulties expressing or evaluating thoughts. Furthermore, sensory–motor exercises can simultaneously activate multiple regulatory systems, including attention, arousal, motor planning, coordination, inhibition, and behavioral adaptation. This wider range of direct experiences may account for the larger improvements observed in both executive functions and social skills.

The persistence of intervention effects at the two-month follow-up is another important finding. Both experimental groups maintained their improvements relative to the control group, and the sensory–motor integration group continued to demonstrate superior outcomes. Maintenance suggests that the observed changes were not simply immediate responses to structured sessions but may have reflected more stable acquisition of regulatory skills. Repeated sensory–motor experiences may strengthen patterns of adaptive sensory processing and coordinated action, while cognitive restructuring may provide strategies that children can continue to apply beyond therapy. Previous research showing improvements in sensory functioning, motor abilities, social skills, and autism-related behaviors after structured intervention provides indirect support for the possibility that systematic practice can produce functionally meaningful changes (Behrouzmanesh et al., 2023; Rezaei & Bakhtiari, 2019; Savarese et al., 2025). The durability found

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in the present study therefore adds practical significance to the immediate posttest effects.

The results should also be interpreted within contemporary perspectives that conceptualize autism as a heterogeneous neurodevelopmental condition rather than a single uniform pattern of deficits. Happé and Frith emphasized major changes in the conceptualization of autism and the importance of recognizing variability across individuals (Happé & Frith, 2020). Niehaus likewise characterized ASD as a complex neurodevelopmental condition with diverse manifestations (Niehaus, 2021). From this perspective, the effectiveness of two theoretically different interventions is unsurprising. Some children may benefit more from bottom-up sensory regulation, while others may respond well to top-down cognitive strategies. The stronger mean effects of sensory–motor integration in the present sample do not imply that cognitive restructuring lacks value; rather, they suggest that intervention selection may need to account for children's individual cognitive, sensory, communicative, and behavioral profiles.

5. Conclusion

Overall, the present findings extend previous evidence by comparing two distinct intervention approaches within the same design and by examining two clinically relevant outcomes simultaneously. The results indicate that both sensory–motor integration and cognitive restructuring can improve executive functions and social skills in children with ASD, while sensory–motor integration may yield comparatively stronger and more durable improvements. These findings are compatible with research demonstrating associations among sensory processing, executive control, motor regulation, and social functioning (Adams et al., 2015; Asadi Gandmani et al., 2016; Garcia & Torres, 2021), as well as studies showing beneficial effects of sensory–motor interventions on autism-related functioning (Nguyen et al., 2021; Sadeghian et al., 2017; Wen & Wu, 2025). At the same time, the significant effects of cognitive restructuring support the continued use of structured cognitive-behavioral techniques for enhancing self-regulation and adaptive functioning in children with ASD (Harris & Thompson, 2023). Taken together, the findings highlight the potential value of interventions that address both bottom-up sensory–motor regulation and top-down cognitive control in the rehabilitation and psychological support of children with autism spectrum disorder.

Several limitations should be considered when interpreting the findings of the present study. First, the sample consisted of only 45 children from specialized autism education and rehabilitation centers in one city, which limits the generalizability of the findings to children with ASD in other geographical, cultural, educational, and clinical settings. Second, purposive sampling was used before random assignment to study groups, and therefore the sample may not fully represent the broader population of children with autism spectrum disorder. Third, the follow-up period was limited to two months and does not establish whether the observed intervention effects persist over longer periods. Fourth, the outcome measures were completed primarily by teachers, which may have introduced observer-related bias and limited the assessment of behavior across home and community environments. Fifth, individual differences in autism severity, intellectual functioning, language ability, sensory profiles, previous rehabilitation experiences, and family involvement may have influenced responsiveness to the interventions but were not examined as moderators. Finally, the relatively brief six-session intervention protocols may not capture the full potential of either treatment approach.

Future studies should replicate these findings with larger and more diverse samples drawn from multiple schools, rehabilitation centers, and geographical regions. Longer follow-up periods, such as six months or one year, are recommended to determine the stability of treatment gains and identify whether booster sessions are necessary. Future research should also incorporate multiple informants, including parents, teachers, clinicians, and direct behavioral observations, to obtain a more comprehensive assessment of change across settings. Researchers may examine whether age, autism severity, cognitive ability, language functioning, sensory-processing profile, or baseline executive-function deficits moderate treatment responsiveness. Comparisons between sensory–motor integration, cognitive restructuring, and combined interventions would also be valuable for determining whether an integrated treatment produces additive or synergistic effects. In addition, future studies could use objective neuropsychological, motor, or physiological measures alongside behavioral rating scales to clarify the mechanisms through which each intervention influences executive and social functioning.

Professionals working with children with autism spectrum disorder may consider incorporating structured sensory–motor activities and cognitive restructuring strategies into individualized rehabilitation and educational

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programs. Sensory–motor exercises can be adapted to children's developmental level and sensory profile and may be particularly useful for children who show difficulties with motor coordination, sensory regulation, attention, or behavioral organization. Cognitive restructuring techniques may be more appropriate for children who possess sufficient verbal and metacognitive abilities to identify thoughts, emotions, and alternative responses. Clinicians and educators should monitor progress across cognitive, behavioral, and social domains rather than focusing exclusively on symptom reduction. Collaboration among psychologists, occupational therapists, teachers, and parents may also facilitate the generalization of acquired skills to classrooms, homes, and community settings. Where feasible, intervention planning should be individualized so that the relative emphasis on sensory–motor and cognitive strategies reflects each child's specific strengths, difficulties, and functional needs.

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

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. The study was approved by the Ethics Committee of Islamic Azad University, Zarand Branch, under ethics code 200146.

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