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Original Article (Pages: 20506-20513)

Sensory-Motor Training for Executive Function in Children with Level 1 ASD

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Abstract

Background: Executive-function difficulties constrain learning and participation in children with autism spectrum disorder (ASD), and evidence for interventions integrating sensory and motor-cognitive demands is limited.

Objective: To examine the association between a combined sensory-integration and perceptual-motor intervention and working memory and response inhibition in children with Level 1 ASD.

Materials and Methods: In this quasi-experimental controlled pretest–posttest study, 30 children with Level 1 ASD (aged 7–10 years; eligibility criterion: 7–12 years) were recruited by convenience sampling from an autism center in Tabriz, Iran, and randomly assigned to an intervention group (n = 15) or a control group (n = 15). The intervention comprised 15 individual 45-minute sessions. Working memory (N-back correct responses), response inhibition (Go/No-Go correct responses), and caregiver-rated executive function difficulties (Coolidge questionnaire total score; lower scores indicate better performance) were assessed before and after the intervention using paired and independent-samples t-tests.

Results: The intervention group improved significantly on Go/No-Go ($t(14) = 16.13$, $p < .001$), N-back ($t(14) = 14.57$, $p < .001$), and Coolidge scores ($t(14) = -10.50$, $p < .001$), whereas controls showed no significant change. Change scores differed significantly between groups for Go/No-Go ($d = 3.44$), N-back ($d = 5.04$), and Coolidge scores ($d = -3.47$; all $p < .001$).

Conclusion: The combined intervention was associated with substantial improvements in laboratory-based and caregiver-rated indicators of executive function. Because the sample was small and controls received no alternative treatment, improvements cannot be attributed solely to the intervention; larger randomized trials with active controls are needed.

Key Words: Autism spectrum disorder; Go/No-Go; Neurodevelopmental condition; N-back; Occupational therapy; Response inhibition; Working memory.

* Please cite this article as: Izadpanah E, Mehdizadeh Fanid L, Kashefi Mehr B. Sensory-Motor Training for Executive Function in Children with Level 1 ASD. J Ped Perspect 2026; 14 (10):20506-20513. **DOI: 10.22038/jpp.2026.99046.5737**

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1- INTRODUCTION

Executive functions are top-down cognitive processes that are central to learning, self-regulation, and participation in daily life (1). Their core components include working memory, inhibitory control, and cognitive flexibility, which are related but separable (1,2). Working memory allows children to maintain and manipulate information, whereas response inhibition supports the suppression of prepotent or contextually inappropriate responses (3). Difficulties in either domain may interfere with following instructions, completing multistep activities, regulating behavior, and engaging in educational and social routines.

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by persistent differences in social communication and restricted, repetitive patterns of behavior; Level 1 ("requiring support") denotes the lowest support-need specifier (4). Executive-function profiles in ASD are heterogeneous rather than uniformly impaired, and a meta-analysis reported executive-function differences in ASD together with marked variation across tasks and participants (5). Intervention effects may therefore depend on cognitive level, sensory responsivity, and the extent to which an intervention engages the targeted process.

Exercise and motor interventions may support executive function because they repeatedly engage attention allocation, response selection, motor planning, and error monitoring (1). A meta-analysis found a small-to-moderate positive effect of chronic exercise on executive function in children and adolescents with ASD, particularly on inhibitory control and cognitive flexibility, but less consistent effects on working memory (6). This suggests a need for interventions that deliberately combine motor demands with cognitive engagement; a cognitive–motor exergame system (NeuroLight) that paired motor responses with working memory and inhibition demands, for example, improved working memory, inhibitory control, and balance in older adults (7).

Ayres Sensory Integration® (ASI®) is an individualized occupational-therapy approach that uses active, play-based sensory-motor challenges. Systematic reviews consider ASI an evidence-based practice for children with autism when fidelity to core principles is demonstrated, while noting the limited number of rigorous studies (8,9); a randomized trial reported improvements in individualized goal attainment, caregiver assistance with self-care, and socialization (10). Evidence for laboratory cognitive outcomes is, however, much weaker. Perceptual-motor training, which targets praxis, postural control, bilateral coordination, and motor planning, may complement ASI by requiring children to interpret sensory information, retain task rules, and inhibit competing responses.

The purpose of this study was to examine whether a combined sensory-integration and perceptual-motor intervention was associated with changes in working memory and response inhibition in children with Level 1 ASD. We hypothesized that relative to controls, children receiving the intervention would show more correct responses on the Go/No-Go and N-back tasks and lower caregiver-rated executive function difficulty scores on the Coolidge questionnaire.

2- MATERIALS AND METHODS

2-1. Study Design and Participants

This quasi-experimental, controlled pretest–posttest study included 30 children with Level 1 ASD in the main analysis. Participants were selected by convenience sampling from the available eligible children; they were then randomly assigned to the intervention group (n = 15)

or the control group (n = 15). Efforts were made to achieve interindividual and group-level matching between and within the groups. Five additional children participated in a feasibility pilot and were excluded from the analyses. Pretest and posttest data were collected by one of the authors at the center over a 3-month therapeutic period, from June 22 to September 22, 2025.

All participants were recruited from the Tabriz Comprehensive Autism Center (Abiler), Iran. Eligibility required (a) a diagnosis of Level 1 ASD (4) confirmed through clinical records and the study's diagnostic screening procedure, (b) an age of 7-12 years (the predefined age criterion), (c) an IQ greater than 75 based on available records, and (d) the ability to participate in behavioral testing. Children were excluded if they had a major visual or hearing impairment, an acute neurological or orthopedic injury, relevant medication changes, simultaneous new treatment, or excessive absence. Although the age criterion allowed children aged 7-12 years, all children who met the eligibility criteria and were enrolled during the recruitment period were aged 7-10 years; no 11- or 12-year-old children were included. The mean age of the participants was 8.37 ± 1.10 years (eight children were 7 years old, nine were 8, seven were 9, and six were 10); 18 were boys, and 12 were girls. The findings therefore apply to children aged 7-10 years.

2-2. Ethical Considerations

The study protocol was approved by the Research Ethics Committee of the University of Tabriz (approval ID: IR.TABRIZU.REC.1404.014; approval date: 27 April 2025 [7 Ordibehesht 1404]). Written informed consent was obtained from the parents or legal guardians of all participating children.

2-3. Intervention

The intervention consisted of 15 individual sessions of approximately 45 min each. The sensory-integration component included individualized vestibular, proprioceptive, tactile, visual, and auditory activities. The perceptual-motor component included graded balance, postural control, bilateral coordination, motor imitation, object control, visual–motor coordination, and fine-motor tasks. The intervention was delivered by trained occupational-therapy personnel; activities were adjusted to each child's tolerance and responses, and safety was monitored throughout. The control group did not receive the study intervention or any alternative, attention-matched, or similar treatment during the intervention period; these children were assessed only at pretest and posttest, and the intervention was offered to them after the study ended.

2-4. Outcome Measures

The outcome measures were selected according to four criteria. First, they had to map directly onto the two executive-function components targeted by the intervention, working memory and response inhibition (1,2). Second, they had to yield objective, quantifiable scores. Third, they had to be simple enough for reliable administration in school-age children with ASD; this criterion was decisive because the pilot phase showed that the original plan to use the Cambridge Neuropsychological Test Automated Battery (CANTAB) was impractical for this population, and CANTAB was therefore not used. Fourth, they had to be compatible with the NeuroLight system, which presents working memory and inhibition challenges and records correct and incorrect responses (7). Two performance-based tasks (N-back and Go/No-Go) were complemented by a caregiver-rated questionnaire so that executive-function difficulties could be examined in structured testing and everyday behavior.

2-4-1. N-back Task

The N-back task requires participants to monitor a continuous stream of stimuli and to decide whether each stimulus matches the one presented n positions earlier, thereby demanding online monitoring, updating, and manipulation of information held in memory (11). These are core operations of working memory, which makes the task a suitable index of the targeted construct. Working memory was indexed by the number of correct responses to an N-back task administered with NeuroLight (7). Pretest and posttest administrations used the same stimulus structure and duration.

2-4-2. Go/No-Go task

In the Go/No-Go task, participants respond to frequent Go stimuli and must withhold their response to infrequent No-Go stimuli. Therefore, successful performance depends on suppressing a prepotent response, the defining feature of response inhibition (3). The task has been used to detect inhibitory-control differences associated with autism (12), and its simple rule structure made it appropriate for children for whom more complex procedures were impractical. Response inhibition was indexed by the number of correct responses on a Go/No-Go task administered with NeuroLight. Incorrect responses were retained for descriptive quality control.

2-4-3. Coolidge Executive-function Questionnaire

Performance-based tasks capture behavior within a brief and structured testing situation, whereas caregiver ratings reflect a child's executive functioning in everyday settings. A caregiver-rated measure was therefore included to determine whether change in laboratory tasks was accompanied by change in daily behavior. Caregivers completed the parent form of the Coolidge executive-function questionnaire based on the Coolidge Personality and Neuropsychological Inventory for Children (13). The questionnaire has 19 items rated on a four-point scale (0 = never, 1 = sometimes, 2 = usually, 3 = always) and comprises three components: decision-making/planning (items 1–8), organization (items 9–16), and inhibition (items 17–19). Component scores are the sum of their item scores, and the total score (possible range 0–57) is the sum of all items. The total score was analyzed in this study. The items describe difficulties (e.g., "My child has difficulty waiting"); higher scores therefore indicate greater difficulty, and a decrease in score represents improvement. In a Persian-language study of children with and without developmental coordination disorder, the content, face, and criterion validity of the questionnaire were judged appropriate, and Cronbach's α was .91 (14).

2-4-4. Psychometric Properties of NeuroLight Tasks

The design of the NeuroLight system and its effects on N-back, Stroop, and balance performance have been described in older adults (7). That report, however, did not provide reliability or validity coefficients for the system's tasks, and it did not examine the Go/No-Go task or children with ASD. The psychometric properties of the NeuroLight N-back and Go/No-Go tasks in this population have therefore not been established; this is acknowledged as a limitation.

2-5. Statistical Analysis

Descriptive statistics (mean ± standard deviation, SD) were calculated for each outcome and group. Paired-samples t tests evaluated within-group pretest–posttest change, with effect sizes expressed as Cohen's dz. Between-group comparisons used independent-samples t tests on change scores (posttest minus pretest), with effect sizes expressed as Cohen's d. Supplementary Mann–Whitney

U tests were used when change-score assumptions were questionable. Statistical significance was set at $p < .05$ (two-tailed). Analyses were performed using IBM SPSS Statistics, version 31 (IBM Corp., Armonk, NY, USA).

3- RESULTS

Thirty children were included in the analyses (15 per group). Descriptive statistics are presented in Table 1, and the results of the within-group and between-group comparisons are presented in Table 2.

3-1. Go/No-Go Performance

The mean number of correct Go/No-Go responses in the intervention group increased by 38.00 responses, a significant improvement with a large effect size. The control group showed no significant change. The between-group comparison of change scores significantly favored the intervention group (Table 2).

3-2. N-back Performance

Correct N-back responses increased significantly in the intervention group (mean change = +9.27), whereas the control group did not change significantly (Table 2). Change scores differed significantly between the groups, and the supplementary Mann–Whitney U test supported this difference ($U = 225$, $p < .001$).

3-3. Coolidge Questionnaire Total Scores

Caregiver-rated Coolidge scores decreased significantly in the intervention group (mean change = −17.53), indicating fewer executive-function difficulties, whereas the control group showed no significant change (Table 2). The reduction was significantly greater in the intervention group, and the supplementary Mann–Whitney U test supported this difference ($U = 0$, $p < .001$).

Table-1. Pretest and posttest descriptive statistics by group and outcome.

Outcome	Group	n	Pretest (mean ± SD)	Posttest (mean ± SD)	Mean change
Go/No-Go (correct responses, n)	Intervention	15	11.73 ± 8.78	49.73 ± 8.88	+38.00
	Control	15	11.80 ± 5.78	16.07 ± 9.75	+4.27
N-back (correct responses, n)	Intervention	15	5.73 ± 2.12	15.00 ± 2.10	+9.27
	Control	15	3.93 ± 1.53	3.87 ± 1.51	−0.07
Coolidge (total score)[a]	Intervention	15	37.47 ± 7.29	19.93 ± 8.18	−17.53
	Control	15	36.00 ± 5.89	35.27 ± 5.01	−0.73

SD: standard deviation. **Mean change:** posttest − pretest.

[a]: Lower Coolidge total scores indicate fewer executive-function difficulties.

Table-2. Within-group and between-group comparisons

Outcome	Intervention, t(14) (p)	dz	Control, t(14) (p)	Between groups, t(28) (p)	d
Go/No-Go (correct responses)	16.13 (<.001)*	4.16	1.58 (.135)	9.43 (<.001)*	3.44
N-back (correct responses)	14.57 (<.001)*	3.76	−0.29 (.774)	13.81 (<.001)*	5.04
Coolidge (total score)[a]	−10.50 (<.001)*	−2.71	−1.26 (.228)	−9.50 (<.001)*	−3.47

Within-group comparisons used paired-samples t tests (effect size dz); between-group comparisons used independent-samples t tests on change scores (effect size d).

[a]: Lower Coolidge total scores indicate fewer executive-function difficulties.

* $p < 0.001$

4- DISCUSSION

In this controlled pretest–posttest study, a 15-session combined sensory-integration and perceptual-motor intervention was associated with improvement on three behavioral indicators of executive function, and the magnitude of change was significantly larger than in the control group for all outcomes. This cross-domain consistency is clinically relevant: the Go/No-Go result suggests improved performance under response-inhibition demands, and the caregiver-rated Coolidge total score, which reflects broader executive-function difficulties that include inhibition, points in the same direction. The N-back result suggests improvement on a working-memory task, but it should not be taken as evidence that all aspects of working memory or executive function improved because executive functions are separable yet related (2). Task performance is also influenced by attention, comprehension, motivation, motor response, and familiarity with the testing procedure.

The findings are compatible with evidence that structured exercise and motor interventions can benefit executive function, especially inhibitory control and cognitive flexibility (1,6), and with findings from combined cognitive–motor training with NeuroLight in older adults (7). They also extend ASI research, which has provided stronger evidence for individualized functioning and participation outcomes than for laboratory cognitive measures (8–10), by examining laboratory cognitive outcomes alongside caregiver-rated response inhibition. The results are therefore promising but preliminary. Importantly, because the sample was small and the control group received neither an alternative treatment nor an attention-matched activity, the between-group differences cannot be attributed with confidence solely to the intervention. Nonspecific factors that differed between the groups, such as additional therapist contact and attention, greater engagement in structured activities, caregiver expectations (caregivers were aware of group allocation when completing the Coolidge questionnaire), and assessment by an unblinded author, may also have contributed to the observed improvements. Additionally, with 15 children per group, chance imbalances between the groups, such as the higher baseline N-back scores in the intervention group, may have influenced the results.

Several mechanisms may contribute to the observed changes. Sensory regulation may reduce the cognitive cost of responding to irrelevant or overwhelming input; perceptual-motor activities require children to maintain rules, monitor performance, inhibit competing actions, and adapt movement to changing demands; and repeated practice within an individualized challenge may strengthen the coupling among perception, action, and executive control. These mechanisms remain hypothetical because mediation was not tested.

4-1. Clinical Implications

Working memory and response inhibition are foundational for following instructions, waiting, switching between activities, managing impulses, and completing self-care sequences (1). A brief, structured, therapist-delivered protocol that can be implemented in occupational therapy settings may therefore have practical value. However, laboratory gains should not automatically be equated with generalized improvements in daily life, and future studies should include goal attainment, participation, caregiver assistance, and other ecological measures.

4-2. Limitations

Several limitations should be considered. First, the small sample limits precision and may inflate effect-size

estimates, and effects of the magnitude observed here are unusually large for behavioral interventions and should be interpreted cautiously. Second, the control group received no alternative, attention-matched, or similar treatment, so the observed improvements cannot be attributed with certainty to the intervention itself; nonspecific effects, such as therapist attention, contact time, and expectancy, cannot be excluded, and neither the assessor nor the caregivers were blinded to group allocation. Third, participants were selected by convenience sampling from a single center and were aged 7 to 10 years, which limits generalizability to older children and other settings. Despite random assignment and matching efforts, the groups differed descriptively at pretest on some outcomes (e.g., N-back performance); baseline equivalence was not statistically evaluated in the analyses reported here. Fourth, the intervention was multicomponent, which prevents separating the effects of sensory integration from those of perceptual-motor training. Fifth, only correct-response counts were analyzed; speed–accuracy trade-offs were not examined, and the Coolidge total score reflects broad executive-function difficulties rather than response inhibition alone. Sixth, the reliability and validity coefficients for the NeuroLight N-back and Go/No-Go tasks have not been established in children with ASD (7). Finally, the data do not establish the maintenance of gains over a longer follow-up.

5- CONCLUSION

A 15-session combined sensory-integration and perceptual-motor intervention was associated with substantial improvements in Go/No-Go performance, N-back performance, and caregiver-rated executive-function difficulties in children aged 7 to 10 years with Level 1 ASD. However, given the small sample size and the absence of an alternative treatment or attention-matched control group, these improvements cannot be attributed with confidence solely to the intervention. The findings support further evaluation of integrated sensory-motor intervention in larger randomized studies with active controls, verified instrument psychometrics, blinded assessment, ecological outcomes, and preregistered analyses.

6- ACKNOWLEDGMENTS

The first author thanks his thesis supervisors for their guidance and support.

7- FUNDING

This study was conducted as part of Erfan Izadpanah's doctoral dissertation at the University of Tabriz. The corresponding author (E.I.) covered all study costs; no external funding was received.

8- CONFLICT OF INTEREST

None declared.

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