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Comparison of the Effectiveness of Vestibular Processing Improvement Therapy and Smart Interactive Wall-Assisted Therapy on the Improvement of Behavior and Social Communication in Children with Autism Spectrum Disorder.

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ABSTRACT

The present study was conducted to compare the effectiveness of vestibular processing improvement therapy and smart interactive wall-assisted therapy on improving behavior and social communication in children with Autism Spectrum Disorder (ASD). The study employed a single-case quasi-experimental design with a multiple-baseline framework. The statistical population consisted of all children diagnosed with Autism Spectrum Disorder who attended specialized autism centers in Birjand, Iran, in 2024. Six children were purposively selected as the sample and were randomly assigned to two groups: vestibular processing therapy (n = 3) and smart interactive wall-assisted therapy (n = 3). The research instruments included the Behavioral Disorders Questionnaire for Children with Autism Spectrum Disorder (2010) and the Vineland Social Maturity Scale (1953). Data were analyzed using reliable change indices, effect size measures, percentage of improvement, and regression analysis. The findings indicated that vestibular processing improvement therapy and smart interactive wall-assisted therapy demonstrated comparable effectiveness in improving behavior and social communication among children with autism ($p < .001$). Given that both interventions were equally effective in enhancing behavioral and social communication outcomes in children with autism, it is recommended that these approaches be incorporated alongside other therapeutic modalities in rehabilitation programs for this population. Their application by parents, educational instructors, and psychologists working with children with autism may contribute to increased awareness of therapeutic strategies aimed at addressing autism-related challenges and enhancing motor functioning, cognitive performance, the development of new neural connections, and behavioral flexibility.

Keywords: Social Communication, Autism, Behavioral Improvement, Vestibular Processing, Smart Interactive Wall.

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Introduction

Autism Spectrum Disorder (ASD) is one of the most prevalent neurodevelopmental disorders and is characterized by persistent deficits in social communication and social interaction, accompanied by restricted, repetitive patterns of behavior, interests, or activities. These impairments emerge during early childhood and substantially affect multiple domains of functioning, including cognitive, emotional,

behavioral, and adaptive development. Recent epidemiological evidence indicates that developmental disabilities, including autism, constitute a major public health concern worldwide, affecting millions of children and adolescents and creating substantial challenges for families, educational systems, and healthcare services (1). Because autism influences fundamental developmental processes that are essential for successful social adaptation, interventions that target social communication and behavioral functioning have become central priorities in rehabilitation and treatment programs.

Among the core symptoms of autism, deficits in social communication are considered particularly significant because they interfere with the child's ability to establish reciprocal relationships, interpret social cues, engage in shared attention, and participate effectively in daily social interactions. Social communication difficulties often manifest as impairments in verbal and nonverbal communication, reduced social reciprocity, limited eye contact, and challenges in understanding others' intentions and emotions. These deficits frequently coexist with stereotyped and repetitive behaviors that further restrict opportunities for meaningful social engagement and adaptive functioning (2, 3). Consequently, interventions that simultaneously address behavioral regulation and social communication are likely to have substantial implications for improving overall functioning in children with autism.

Research has consistently demonstrated that social communication development plays a critical role in the long-term outcomes of children with autism. Joint attention, social reciprocity, imitation, and language development are strongly associated with later adaptive functioning and social competence. For example, joint attention abilities have been identified as important predictors of social and cognitive development among children with autism, influencing communication skills and broader adaptive outcomes (4). Similarly, responsiveness to joint attention and object imitation has been shown to predict expressive and receptive language growth in young children on the autism spectrum, highlighting the importance of early interventions that strengthen social engagement capacities (5). Given these developmental associations, improving social communication is not merely a symptom-focused objective but a pathway toward enhancing broader developmental trajectories.

Theoretical models of autism increasingly emphasize the interaction between sensory processing deficits and social-behavioral functioning. Sensory integration theories suggest that atypical processing of sensory information may contribute to difficulties in attention, emotional regulation, motor coordination, and social participation. Many children with autism exhibit abnormalities in vestibular, proprioceptive, tactile, auditory, and visual processing systems, which can interfere with their ability to interact effectively with their environment. Sensory integration difficulties have been linked to deficits in motor planning, postural control, executive functioning, and adaptive behavior, all of which influence social communication and behavioral regulation (6, 7). Consequently, interventions targeting sensory processing mechanisms have gained increasing attention as promising approaches for improving functional outcomes in autism.

Among sensory systems, the vestibular system occupies a particularly important role because it contributes to balance, postural control, spatial orientation, motor coordination, and the integration of sensory information across multiple modalities. Emerging evidence suggests that vestibular dysfunction is relatively common among children with autism and may represent an underrecognized contributor to behavioral and developmental difficulties. Vestibular deficits can adversely affect motor performance, sensory regulation, attention, and social participation, thereby exacerbating the challenges experienced by

children with autism (8). Furthermore, sensory-motor processing abnormalities have been associated with impaired balance behavior and atypical movement patterns, underscoring the importance of interventions that strengthen vestibular functioning and sensory integration (9).

Vestibular-based interventions seek to improve neurological organization and sensory integration through activities that stimulate the vestibular system and promote adaptive responses to sensory input. Such interventions often include balance exercises, rotational movements, postural control activities, and coordinated motor tasks designed to enhance sensory processing and motor regulation. Previous studies have reported promising outcomes associated with vestibular stimulation and sensory integration programs. Dehghani et al. demonstrated that vestibular stimulation significantly improved social development among children with Autism Spectrum Disorder (10). Similarly, Velayati Haghighi et al. found that vestibular-system-based balance training improved both postural stability and social skills performance in children with autism (11). Additional evidence indicates that psychomotor rehabilitation interventions emphasizing sensory integration can improve postural control and sensory functioning in children with autism, thereby supporting broader developmental gains (7). Sensory integration training has also been associated with improvements in balance function and executive functioning, suggesting that vestibular interventions may exert effects beyond motor performance alone (6). Likewise, extracurricular physical activity programs designed to enhance balance have demonstrated positive effects on motor and adaptive outcomes among children with autism (12).

Although vestibular-based interventions have demonstrated considerable promise, advances in digital technology have introduced new therapeutic possibilities for autism rehabilitation. The integration of virtual reality, interactive environments, and digital rehabilitation technologies has created opportunities to deliver engaging, individualized, and multisensory interventions that address multiple developmental domains simultaneously. Technology-assisted interventions are particularly attractive because they can increase motivation, sustain attention, provide immediate feedback, and facilitate repetitive practice within structured learning environments. Recent research has highlighted the effectiveness of various technology-based approaches in improving cognitive, behavioral, and social outcomes among children with autism (13, 14).

One emerging technology in this field is the smart interactive wall, which combines motion detection, touch-sensitive interfaces, visual feedback, and interactive digital content within a multisensory therapeutic environment. Interactive wall systems create opportunities for children to engage actively with virtual stimuli through body movements, gestures, and coordinated actions. These environments may simultaneously stimulate sensory, cognitive, motor, and social processes, thereby promoting learning and behavioral adaptation. Theoretical foundations for interactive multisensory environments suggest that they can facilitate attention regulation, sensory integration, social engagement, and adaptive behavior among children with autism (15). Furthermore, immersive virtual reality and role-playing technologies have demonstrated effectiveness in improving social reciprocity and social interaction skills in children with Autism Spectrum Disorder (14).

Recent investigations have further supported the potential of technology-enhanced interventions for improving social communication. Active video games and technology-based movement activities have been shown to enhance social communication outcomes among children with autism, likely through increased

engagement and opportunities for interactive participation (16). Similarly, cognitive rehabilitation programs delivered through technology-assisted platforms have demonstrated positive effects on communication, language development, and symptom reduction in children with autism (17). Computer game-based cognitive rehabilitation has also been associated with improvements in functional performance and adaptive skills among children with Autism Spectrum Disorder (13). Collectively, these findings suggest that interactive digital environments may provide valuable opportunities for enhancing both behavioral and social outcomes.

Beyond sensory and technological interventions, a broad range of rehabilitation programs have been developed to address the multidimensional challenges associated with autism. Structured educational interventions such as the TEACCH program have demonstrated effectiveness in promoting developmental and adaptive functioning among preschool children with Autism Spectrum Disorder (18). Parent-training programs have also been shown to improve daily living skills and support adaptive development in adolescents with autism, highlighting the importance of comprehensive intervention frameworks (19). Furthermore, interventions targeting stereotyped behaviors through structured activities and music programs have yielded beneficial outcomes, emphasizing the potential value of multimodal rehabilitation approaches (20).

The importance of social development in childhood extends beyond autism-specific research. Studies conducted among typically developing children have consistently identified social development as a fundamental determinant of psychological adjustment, academic readiness, and interpersonal competence. Social development is influenced by a variety of factors, including parenting practices, empathy, intelligence, movement experiences, and opportunities for social interaction (21-23). Research has further demonstrated that movement-based interventions can contribute positively to social and psychological development in young children (24). Play-based interventions have similarly been shown to enhance social development, self-concept, and perceived competence among children with developmental challenges (25). These findings reinforce the notion that interventions integrating motor, cognitive, and social experiences may be particularly beneficial for children experiencing developmental difficulties.

In addition to behavioral and sensory factors, emotional and interpersonal processes contribute substantially to social functioning in autism. Recent evidence suggests that emotion regulation serves as an important mechanism linking attachment patterns, social skills, and anxiety among children with Autism Spectrum Disorder (2). These findings indicate that interventions capable of simultaneously influencing sensory regulation, emotional adaptation, and social engagement may produce broader developmental benefits. Because both vestibular-based therapies and interactive digital interventions provide opportunities for structured engagement, sensory modulation, and active participation, they may support improvements across multiple functional domains.

Despite growing evidence supporting both vestibular rehabilitation and technology-assisted interventions, several important gaps remain in the literature. First, most studies have examined these approaches independently rather than comparing their relative effectiveness. Second, although vestibular stimulation interventions have demonstrated positive effects on social development and social skills, fewer studies have directly evaluated their impact on both behavioral problems and social communication simultaneously (10, 11). Third, research investigating interactive multisensory technologies has primarily

focused on virtual reality, active video games, or computer-assisted interventions, while evidence regarding smart interactive wall systems remains limited (15, 16). Finally, there is a scarcity of single-case experimental studies that allow detailed examination of individual response patterns and treatment effects in children with severe functional limitations associated with autism.

Given the increasing recognition of sensory integration deficits in autism, the promising outcomes associated with vestibular rehabilitation, and the expanding role of interactive digital technologies in developmental intervention, direct comparisons between these therapeutic approaches are both theoretically and clinically important. Such comparisons can contribute to evidence-based decision-making regarding intervention selection and resource allocation within autism rehabilitation services. Moreover, identifying whether traditional sensory-based approaches and contemporary technology-assisted interventions produce comparable outcomes may assist clinicians, educators, and families in designing individualized treatment plans tailored to the needs and preferences of children with Autism Spectrum Disorder.

Therefore, the present study aimed to compare the effectiveness of vestibular processing improvement therapy and smart interactive wall-assisted therapy on improving behavior and social communication in children with Autism Spectrum Disorder.

Methods and Materials

Study Design and Participants

In terms of objective, the present study was applied research; in terms of data collection method, it was classified as survey research; and in terms of implementation method, it was a single-case quasi-experimental study. Among single-case quasi-experimental designs, a pretest–posttest–follow-up quasi-experimental design, namely a multiple-baseline design, was selected because this type of design is an appropriate research tool for practical and clinical studies aimed at determining the effectiveness of clinical treatment models. In this design, there is no control group, and each patient's baseline serves as his or her own control condition.

The statistical population consisted of all children with Autism Spectrum Disorder (ASD) who attended specialized autism centers in Birjand in 2024. Therefore, using purposive sampling, children with Autism Spectrum Disorder who attended one of the specialized autism centers in Birjand and whose diagnosis of autism had previously been confirmed by a psychiatrist were first identified. Among them, children with severe functional limitations according to the International Classification of Functioning, Disability and Health (ICF), as determined by the Disability Assessment Commission of the Birjand Welfare Organization, were selected. To determine the severity of the children's functional limitations, their medical records at the Welfare Organization of Birjand County were reviewed. Subsequently, after obtaining written informed consent from their parents, six children were selected to participate in the study and were randomly and equally assigned to two groups: vestibular processing-based therapy (n = 3) and smart interactive wall-assisted therapy (n = 3). The inclusion criteria were diagnosis of Autism Spectrum Disorder and severe functional limitation, absence of other psychological disorders according to psychiatric records, and no medication use or participation in other therapeutic programs during the intervention. The exclusion criteria

were unwillingness to participate in the study and absence from the therapeutic process for more than one session.

To conduct this study, the necessary permission to implement the research in a specialized autism center was first obtained from the Welfare Organization of Birjand County in 2024. Then, one center was purposively selected, and after coordination with the center authorities and presentation of the authorization, six children with Autism Spectrum Disorder who had severe functional limitations according to the International Classification of Functioning, Disability and Health (ICF), as determined by the Disability Assessment Commission of the Birjand Welfare Organization, were selected as the study sample after obtaining written informed consent from their parents. They were then randomly and equally assigned to two groups: vestibular processing-based therapy (n = 3) and smart interactive wall-assisted therapy (n = 3). The characteristics of these six children were as follows: their ages ranged from 4 to 6 years, and the sample included four boys and two girls. After the parents of all six children completed the behavioral disorders and social communication questionnaires at baseline, the participants in the first group received vestibular processing improvement therapy for 10 sessions at one of the specialized autism centers in Birjand. The participants in the second group received smart interactive wall-assisted therapy for 10 sessions. It should be noted that the therapeutic interventions were implemented under supervision and according to standardized therapeutic programs by experienced specialists in neuro-auditory rehabilitation for the first group and by information and communication technology specialists for the second group. During both interventions, the participating children in both groups were assessed in four stages in terms of behavioral disorders and social communication. Finally, two weeks after the completion of the interventions, for follow-up purposes, the parents of all participants completed the research questionnaires once again. To observe ethical considerations in the present study, a brief explanation was first provided to the parents of the participating children regarding the purpose of the study, the method of cooperation, the benefits and advantages of participation, and the purpose of completing the questionnaires. Ethical considerations consistent with the publication guidelines of the American Psychological Association and the ethical codes of the Iranian Psychological Association, including confidentiality, preservation of data privacy, and obtaining written consent from the sample members, were observed in this study.

Participants in the vestibular processing-based therapy experimental group received five to six vestibular stimulation exercises in each session according to the neuro-auditory rehabilitation or insight-based therapy package, aimed at activating the vestibular system of the brain.

Data Collection

1. Behavioral Disorders Questionnaire for Children with Autism Spectrum Disorder (Parent Form) (2010): This questionnaire was designed and developed by Bardideh et al. It consists of 40 items and has a unidimensional structure. It is scored on a five-point Likert scale ranging from 1 (very low) to 5 (very high). A higher score on this questionnaire indicates a higher level of behavioral disorders in children with autism. The validity of this questionnaire was confirmed through factor analysis, indicating the presence of one general factor with an eigenvalue of 13.708 and an explained variance of 34.269%. The Cronbach's alpha coefficient calculated for this questionnaire was estimated at .94. In addition, convergent validity between the Rutter Children's Behavioral Disorder Test and the Behavioral Disorders Questionnaire

for Children with Autism Spectrum Disorder was confirmed with a coefficient of .81. The face and content validity of this questionnaire were confirmed based on the opinions of experts in Autism Spectrum Disorders and psychology using content validity index and content validity ratio methods (Bardideh et al., 2010).

2. Vineland Social Maturity Scale (1953): The Vineland Social Maturity Scale was developed by Doll in 1953 and was translated and validated in Iran by Baraheni et al. in 1978. This questionnaire was designed for the age range of 0 to 25 years and is particularly applicable for individuals with intellectual disabilities. It consists of 117 items and is divided into one-year age groups. For each item, the required information is obtained not through test situations but through interviews with caregivers, including the father, mother, other family members, or teacher, or with the examinee. The basis of this scale is what the individual is capable of doing in daily life. This scale is divided into eight categories: general self-help (items 2, 3, 5, 6, 8, 9, 11, 13, 15, 21, 23, 30, 38, 39, 46, and 60), self-help eating (items 16, 20, 25, 26, 29, 33, 34, 56, 62, and 70), self-help dressing (items 19, 32, 35, 37, 42, 43, 47, 58, 59, 61, 67, and 80), self-direction (items 69, 110, 77, 81, 85, 86, 89, 91, 93, 94, 95, 96, 98, and 99), occupation (items 4, 18, 22, 31, 36, 44, 49, 51, 65, 68, 107, 108, 109, 74, 76, 83, 92, 100, and 106), verbal communication (items 12, 17, 40, 48, 55, 71, and 90), locomotion (items 1, 10, 27, 28, 52, 57, 66, 72, 73, 75, 78, 84, 87, and 88), and socialization (items 7, 14, 24, 41, 45, 50, 53, 63, 64, 111, 79, 82, 97, 101, 102, and 105). Based on the individual's scores in the eight categories of this scale, social age and social quotient can be calculated. The scoring of this questionnaire is conducted as follows: a score of 1 is assigned when the examinee performs the task with complete success, when the examinee is capable of performing the task but the parents have not yet allowed him or her to perform that behavior, or when the individual has not performed the behavior due to a specific reason or limitation but would be able to perform it if the limitation were removed. A score of 0.5 is assigned when the examinee sometimes performs the task and sometimes does not, meaning that the skill has not yet been fully acquired. A score of 0 is assigned when the individual cannot perform the task, when the individual cannot perform the behavior due to irreversible disabilities or limitations, when the individual does not perform the task and would perform it very poorly even under strong pressure, or when the examinee has not yet reached the developmental stage required to perform the task. Baraheni et al. (1978) estimated the validity of this questionnaire at .81 and reported its reliability as .73 using Cronbach's alpha and .92 using the test–retest method. In the present study, items related to the age range of 4 to 5 years were used. In addition, the Vineland Social Maturity Scale (1953) has been confirmed and used in various studies.

Intervention

A) General balance exercises: These included jumping on a trampoline; standing, sitting, and squatting on a balance therapy ball; assuming various standing, kneeling, and quadruped positions on a rotary board; using a scooter board; walking on a balance beam; performing rotational and linear movements forward, backward, left, and right on a regular swing; crossing obstacles; rolling; walking on spiral paths; running on spiral paths; moving a rolling pin under the feet; simple backward movement; and difficult backward movement.

B) Postural stability exercises: These included standing on one foot with eyes open and closed; standing with feet placed one behind the other; moving backward and forward; gaze fixation and standing while changing the distance between the feet; exercises with a headlamp; head rotations; head–trunk

rotations; head rotation while walking; visual focusing using a ball; exercises on an inclined surface; various lying and sitting positions; maintaining balance on a narrow training board; going up and down stairs; using eye movements to stabilize gaze; simultaneous use of vestibular and somatosensory inputs; simultaneous use of visual and vestibular inputs; using all senses for postural control; and using all senses for body postural control.

Smart interactive wall-assisted therapy was also implemented based on a virtual reality interaction intervention program. It was conducted in a room equipped with a display screen containing touch and motion sensors. To enhance the ability of children with autism to respond to touch or movement, the system used information received from three-dimensional cameras to guide and control activities on the wall.

Data Analysis

To examine the statistical significance of score changes from the baseline phase to the intervention phase, the Reliable Change Index (RCI) was used, with values greater than 1.96 considered statistically significant. The effect size index (ES) was used to measure the effectiveness of each intervention, with effect sizes lower than .20 considered small, .50 considered moderate, and greater than .80 considered large. In addition, the percentage of improvement index was used to assess the participants' progress in improving outcomes, with values greater than 50% considered statistically significant. To compare baseline and treatment results at the group level, changes in the level and trend of the dependent variables were examined using mixed regression.

Findings and Results

In this study, six children with Autism Spectrum Disorder were examined in two three-member groups: vestibular processing improvement therapy and smart interactive wall-assisted therapy. Three children (50%) were 4 years old, and three children (50%) were 5 years old.

The statistical data related to each participant are presented in Tables 1 and 2. These tables include between-condition changes for each variable from the baseline phase (A) to the intervention phase (B), including change in trend direction, change in stability, change in level (relative, absolute, median, and mean changes), percentage of non-overlapping data (PND), percentage of overlapping data (POD), Reliable Change Index (RCI), effect size (ES), and percentage of improvement. In the data analysis, the first three participants belonged to the vestibular processing improvement therapy group, and the second three participants belonged to the smart interactive wall-assisted therapy group.

Table 1. Visual–Inferential Analysis of Between-Condition Changes in Vestibular Processing Improvement Therapy and Smart Interactive Wall-Assisted Therapy on Behavioral Improvement

Between-condition changes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Condition comparison	B/A	B/A	B/A	B/A	B/A	B/A
Target-dependent effect	Positive	Positive	Positive	Positive	Positive	Positive
Stability change	Stable to stable	Stable to stable	Stable to stable	Stable to stable	Stable to stable	Stable to stable
Relative level change	120 to 95	123 to 97	126.5 to 101.5	124 to 99.5	134.5 to 105	126 to 93
Absolute level change	120 to 104	122 to 107	128 to 113	124 to 107	135 to 116	124 to 99
Median level change	119 to 80.5	123 to 79.5	127 to 82	124 to 85	134.5 to 86	125 to 79.5

Mean level change	119.33 to 81.5	123.25 to 81.7	126.6 to 85	123.66 to 85.2	134.25 to 88.7	126 to 80.7
Percentage of non-overlapping data (PND)	100%	100%	100%	100%	100%	100%
Percentage of overlapping data (POD)	0%	0%	0%	0%	0%	0%
Reliable Change Index (RCI)	2.08	2.13	2.47	2.08	2.19	3.84
Effect size (ES)	2.68	2.94	2.92	2.68	3.02	4.47
Percentage of improvement	31.70	33.67	32.85	31.06	33.90	35.92
Overall effect size	2.84	2.84	2.84	3.39	3.39	3.39
Overall percentage of improvement	32.74	32.74	32.74	33.62	33.62	33.62

Based on Table 1, the mean score of all participants in both treatment methods, namely vestibular processing improvement therapy and smart interactive wall-assisted therapy, decreased from the baseline phase to the intervention phase in the behavior variable. In addition, the percentage of non-overlapping data (100%) and the percentage of overlapping data (0%) for all six participants indicate that all data in the intervention condition were outside the range of the baseline condition. The Reliable Change Index values indicate that the change in the behavior scores of children with Autism Spectrum Disorder from the baseline phase to the intervention phase was statistically significant. Moreover, the effect size values indicate the effective role of vestibular processing improvement therapy and smart interactive wall-assisted therapy in the behavior of children with Autism Spectrum Disorder. Considering the participants' percentage of improvement and the overall percentage of improvement, this degree of improvement in the intervention phase was not clinically significant. According to Figures 1 and 2, this degree of improvement was significant at the follow-up phase. Therefore, the results indicate that participants in both groups demonstrated an appropriate therapeutic alliance during treatment. Comparing the overall percentage of improvement and the overall effect size of the participants in the two treatment groups showed that vestibular processing improvement therapy and smart interactive wall-assisted therapy had equal effectiveness in improving the behavior of children with Autism Spectrum Disorder.

Table 2. Visual–Inferential Analysis of Between-Condition Changes in Vestibular Processing Improvement Therapy and Smart Interactive Wall-Assisted Therapy on Social Communication Improvement

Between-condition changes	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Condition comparison	B/A	B/A	B/A	B/A	B/A	B/A
Target-dependent effect	Positive	Positive	Positive	Positive	Positive	Positive
Stability change	Stable to stable	Stable to stable	Stable to stable	Stable to stable	Stable to stable	Stable to stable
Relative level change	3 to 3.5	2 to 3.5	2.5 to 4	2 to 3	2.5 to 4	2.5 to 3.5
Absolute level change	3 to 3	2 to 3	2 to 4	2 to 3	2 to 4	2 to 3
Median level change	2 to 4.5	2 to 4	2 to 4	2 to 3.5	2 to 4	2 to 4.5
Mean level change	2.33 to 4.25	2.25 to 3.75	2.4 to 4.25	2 to 3.5	2.25 to 4.25	2.2 to 4.25
Percentage of non-overlapping data (PND)	75%	75%	100%	100%	100%	75%
Percentage of overlapping data (POD)	25%	25%	0%	0%	0%	25%
Reliable Change Index (RCI)	2.01	3.06	4.77	2.59	4.09	2.77
Effect size (ES)	2.32	3.01	3.51	3.36	4.00	2.88
Percentage of improvement	82.14	66.66	77.08	75.00	88.88	93.18
Overall effect size	2.94	2.94	2.94	3.41	3.41	3.41
Overall percentage of improvement	75.29	75.29	75.29	85.66	85.66	85.66

Based on Table 2, the mean score of all participants in both treatment methods, namely vestibular processing improvement therapy and smart interactive wall-assisted therapy, increased from the baseline phase to the intervention phase in the social communication variable. In addition, for the first, second, and sixth participants, the percentage of non-overlapping data was 75% and the percentage of overlapping data was 25%; for the other participants, the percentage of non-overlapping data was 100% and the percentage of overlapping data was 0%. Therefore, the findings indicate that most data in the intervention condition were outside the range of the baseline condition. The Reliable Change Index values indicate that the change in the social communication scores of children with Autism Spectrum Disorder from the baseline phase to the intervention phase was statistically significant. Moreover, the effect size values indicate the effective role of vestibular processing improvement therapy and smart interactive wall-assisted therapy in the social communication of children with autism. Considering the participants' percentage of improvement and the overall percentage of improvement, this degree of improvement in the intervention phase was clinically significant. According to Figures 1 and 2, this degree of improvement was significant at the follow-up phase. Therefore, the results indicate that participants in both groups demonstrated an appropriate therapeutic alliance during treatment. Comparing the overall percentage of improvement and the overall effect size of the participants in the two treatment groups showed that vestibular processing improvement therapy and smart interactive wall-assisted therapy had equal effectiveness in improving social communication among children with Autism Spectrum Disorder.

Table 3. Mixed Regression Analysis Findings for the Research Variables in the Treatment Groups

Treatment group	Variable	Predictor	Unstandardized coefficient	Standardized coefficient	SE	t	p	95% CI lower bound	95% CI upper bound
Vestibular processing improvement therapy	Behavior	Intercept	121.04	—	2.61	46.50	< .001	115.66	126.43
Vestibular processing improvement therapy	Behavior	Trend in the first phase	1.02	.102	.864	1.175	.252	−.77	2.80
Vestibular processing improvement therapy	Behavior	Level change from the first to the second phase	−10.304	−.194	3.347	−3.078	.005	−17.22	−3.38
Vestibular processing improvement therapy	Behavior	Trend change from the first to the second phase	−13.214	−.915	1.210	−10.918	< .001	−15.71	−10.71
Vestibular processing improvement therapy	Social communication	Intercept	2.184	—	.302	7.237	< .001	1.56	2.80
Vestibular processing improvement therapy	Social communication	Trend in the first phase	.058	.151	.100	.576	.571	−.15	.26
Vestibular processing	Social communication	Level change	1.15	.56	.38	2.96	.007	.34	1.95

improvement therapy		from the first to the second phase							
Vestibular processing improvement therapy	Social communication	Trend change from the first to the second phase	.109	.197	.140	.777	.445	−.18	.399
Smart interactive wall-assisted therapy	Behavior	Intercept	130.14	—	3.085	42.189	< .001	123.76	136.52
Smart interactive wall-assisted therapy	Behavior	Trend in the first phase	−.76	−.075	1.02	−.749	.461	−2.88	1.35
Smart interactive wall-assisted therapy	Behavior	Level change from the first to the second phase	−12.247	−.225	3.967	−3.088	.005	−20.45	−4.04
Smart interactive wall-assisted therapy	Behavior	Trend change from the first to the second phase	−10.667	−.720	1.434	−7.436	< .001	−13.63	−7.70
Smart interactive wall-assisted therapy	Social communication	Intercept	1.73	—	.278	6.241	< .001	1.16	2.31
Smart interactive wall-assisted therapy	Social communication	Trend in the first phase	.167	.419	.092	1.812	.083	−.024	.358
Smart interactive wall-assisted therapy	Social communication	Level change from the first to the second phase	.997	.469	.357	2.788	.010	.25	1.73
Smart interactive wall-assisted therapy	Social communication	Trend change from the first to the second phase	.033	.057	.129	.254	.800	−.23	.30

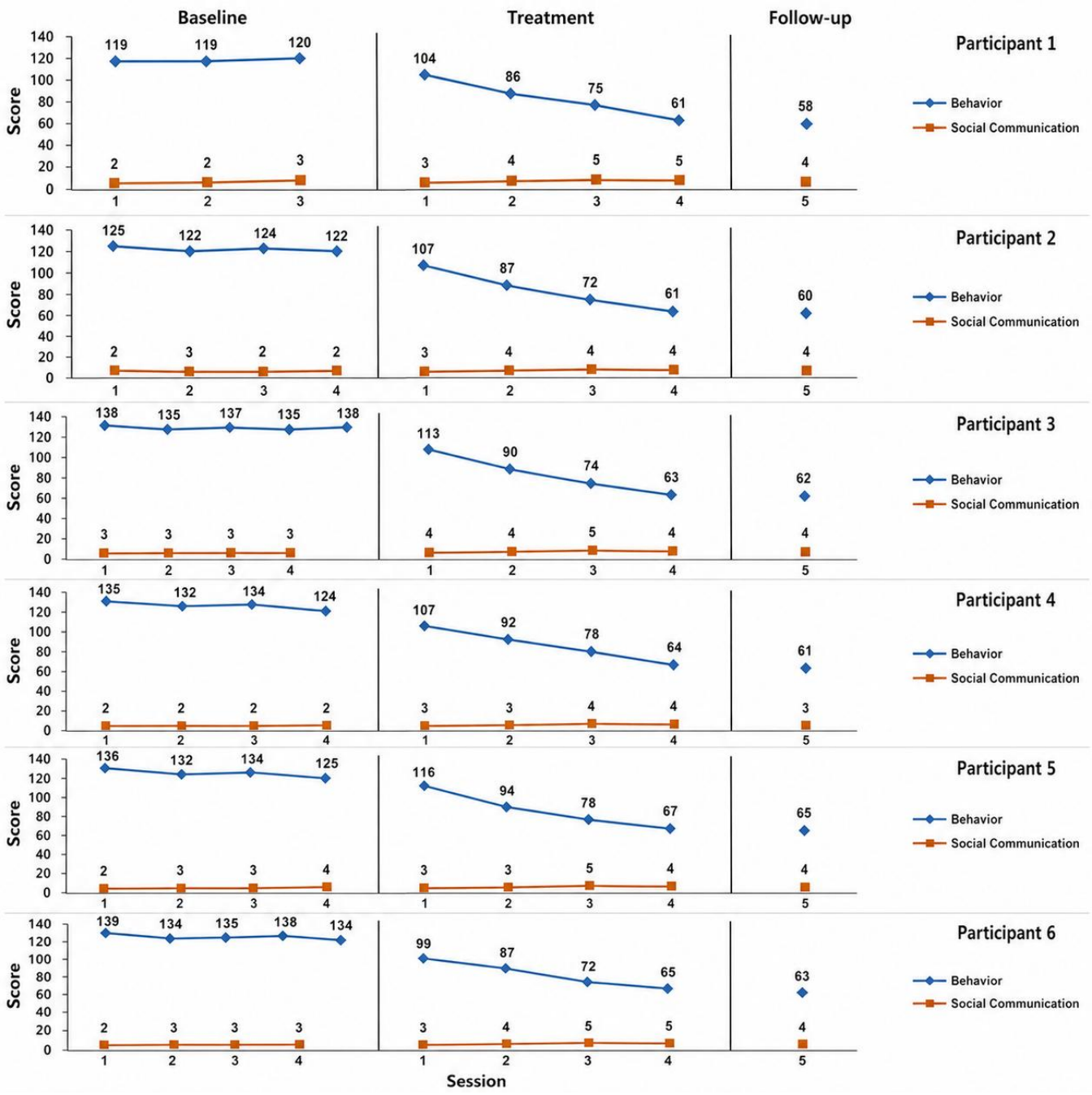

Figure 1. Scores of the Participants on the Research Variables

The results of the mixed regression analysis examining changes in the level and trend of the research variables according to vestibular processing improvement therapy and smart interactive wall-assisted therapy are presented in Table 3. Given that, for the behavior variable, both the level change from the first to the second phase and the trend change from the first to the second phase were significant in both treatment methods, the two therapeutic approaches were effective in improving the behavior of children with Autism Spectrum Disorder both in the short term, or immediately, and in the long term over time. In addition, for the social communication variable, only the level change from the first to the second phase was significant in both vestibular processing improvement therapy and smart interactive wall-assisted therapy.

Therefore, both treatment methods were effective in improving the social communication of children with Autism Spectrum Disorder in the short term, or immediately.

Discussion and Conclusion

The present study aimed to compare the effectiveness of vestibular processing improvement therapy and smart interactive wall-assisted therapy on behavioral problems and social communication among children with Autism Spectrum Disorder (ASD). The findings demonstrated that both intervention approaches produced significant improvements in the targeted outcomes. Specifically, behavioral problem scores decreased substantially from the baseline phase to the intervention phase in both treatment groups, while social communication scores increased across participants receiving either vestibular processing-based intervention or smart interactive wall-assisted therapy. The visual analysis indicators, including the percentage of non-overlapping data, Reliable Change Index values, effect sizes, and mixed regression analyses, confirmed the effectiveness of both interventions. Moreover, comparison of the overall effect sizes and improvement percentages indicated that neither intervention demonstrated superiority over the other, suggesting that vestibular processing improvement therapy and smart interactive wall-assisted therapy were similarly effective in improving behavioral functioning and social communication in children with ASD.

The first major finding of the study was that vestibular processing improvement therapy significantly reduced behavioral problems among children with autism. This finding is theoretically consistent with sensory integration perspectives, which propose that many maladaptive behaviors observed in children with autism arise from difficulties in processing and organizing sensory information. When vestibular functioning is impaired, children may experience difficulties in postural control, body awareness, self-regulation, and environmental adaptation, which can manifest as stereotyped behaviors, irritability, attention difficulties, and behavioral dysregulation. By providing structured vestibular stimulation, the intervention likely facilitated more efficient sensory integration processes and improved the children's capacity to regulate their responses to environmental stimuli. The observed reduction in behavioral difficulties is consistent with previous research demonstrating beneficial effects of sensory integration and vestibular stimulation interventions on developmental and behavioral outcomes in children with autism (10, 11). Furthermore, studies examining psychomotor rehabilitation and sensory integration training have reported improvements in sensory processing, postural control, and executive functioning, which may indirectly contribute to reductions in maladaptive behaviors and improvements in adaptive functioning (6, 7).

The effectiveness of vestibular processing improvement therapy may also be understood through neurodevelopmental mechanisms. The vestibular system plays a central role in coordinating sensory information from multiple modalities and contributes to the development of motor planning, balance, attention, and emotional regulation. Research has suggested that vestibular and balance deficits are common among children with autism and may represent an important yet often overlooked aspect of the disorder (8). Improving vestibular functioning may therefore strengthen neural networks responsible for self-regulation and environmental adaptation. Enhanced postural stability and sensory processing may reduce the need for compensatory stereotyped behaviors and increase the child’s ability to engage appropriately with social and environmental demands. The current findings support previous evidence indicating that vestibular-system-based balance training can improve social skills and adaptive performance among children with ASD (11).

Moreover, findings from studies investigating motor-sensory processing suggest that improvements in sensory organization are associated with more efficient behavioral regulation and adaptive functioning (9).

Another important finding was that vestibular processing improvement therapy significantly enhanced social communication among participating children. Social communication difficulties are among the core characteristics of autism and are closely linked to broader developmental outcomes. Improved vestibular functioning may support social communication through several pathways. First, enhanced sensory integration can increase the child's ability to attend to social stimuli and respond appropriately to social cues. Second, improvements in balance, motor coordination, and body awareness may facilitate participation in social interactions and cooperative activities. Third, better sensory regulation may reduce anxiety and overstimulation, allowing greater engagement in communicative exchanges. These explanations are supported by studies demonstrating that vestibular stimulation and sensory integration interventions improve social development and social skills in children with autism (10, 11). Additionally, sensory integration training has been shown to improve executive functioning and attentional processes that are closely associated with successful social communication (6).

The findings related to social communication are also consistent with developmental research emphasizing the importance of sensory-motor foundations for social functioning. Joint attention, imitation, and reciprocal interaction are critical components of social communication development, and these capacities depend partly on effective sensory processing and attentional regulation. Previous studies have demonstrated that joint attention abilities contribute significantly to communication outcomes and social adaptation among children with autism (4). Likewise, responsiveness to social stimuli and imitation skills have been shown to predict language development and communication growth (5). Consequently, interventions that strengthen sensory integration may create a more stable foundation for the acquisition and expression of social communication skills.

The second major finding of the present study was that smart interactive wall-assisted therapy produced significant improvements in both behavioral functioning and social communication. This finding highlights the therapeutic potential of technology-assisted interventions for children with Autism Spectrum Disorder. Smart interactive walls provide a multisensory environment in which children interact with visual, auditory, and movement-based stimuli in a structured and engaging manner. Such environments may enhance attention, motivation, participation, and learning through immediate feedback and active engagement. Children with autism often demonstrate greater responsiveness to technology-mediated learning environments than to conventional instructional formats because digital systems offer predictable, visually rich, and highly structured interactions. These characteristics may explain the substantial improvements observed among participants receiving smart interactive wall-assisted therapy.

The positive effects of smart interactive wall-assisted therapy are consistent with previous studies examining technology-based interventions for autism. Research on virtual reality environments, computer-assisted interventions, and active video games has demonstrated significant improvements in social communication, cognitive functioning, and adaptive behavior among children with ASD (13, 14, 16). Interactive technologies provide opportunities for repeated practice of social and behavioral skills within controlled environments while maintaining high levels of engagement and motivation. The current findings

extend this body of evidence by suggesting that smart interactive wall systems may serve as an effective platform for promoting behavioral and social development in children with autism.

The effectiveness of smart interactive wall-assisted therapy can also be interpreted through theories of multisensory learning and environmental enrichment. Interactive wall systems require children to integrate visual information, motor responses, spatial awareness, and attentional processes while engaging in meaningful tasks. Such activities may strengthen neural pathways involved in cognitive flexibility, sensory integration, and behavioral regulation. Previous work has highlighted the benefits of interactive multisensory environments for children with autism, emphasizing their capacity to improve attention, engagement, and adaptive functioning (15). Furthermore, immersive virtual reality interventions have been shown to enhance social reciprocity and social interaction skills through repeated exposure to simulated social experiences (14). The current findings suggest that smart interactive wall systems may provide similar benefits while offering additional opportunities for physical movement and sensory engagement.

An important aspect of the present findings is that the two intervention approaches demonstrated comparable levels of effectiveness. The absence of significant differences between vestibular processing improvement therapy and smart interactive wall-assisted therapy suggests that both interventions may influence common developmental mechanisms despite relying on different therapeutic modalities. Both interventions provide rich sensory experiences, encourage active participation, and require continuous interaction with the environment. Vestibular therapy primarily targets sensory processing and motor regulation through physical activities, whereas smart interactive wall-assisted therapy combines sensory stimulation with digital engagement and interactive learning. Nevertheless, both approaches appear capable of improving sensory integration, attention regulation, behavioral adaptation, and social responsiveness. This convergence may explain why both treatments produced similar outcomes.

The comparable effectiveness of the two interventions may also reflect the multidimensional nature of autism rehabilitation. Contemporary perspectives increasingly emphasize the importance of individualized and multimodal interventions that address cognitive, sensory, motor, emotional, and social domains simultaneously. Structured rehabilitation programs, including sensory integration approaches, educational interventions, parent training, movement-based activities, and technology-assisted programs, have all demonstrated positive effects on developmental outcomes among children with autism (18-20). Therefore, it is possible that multiple intervention pathways can lead to similar improvements when they successfully engage core developmental processes related to attention, sensory regulation, and social interaction.

The current findings also align with broader developmental research emphasizing the interconnected nature of motor, social, cognitive, and emotional development. Studies involving both typically developing children and children with developmental challenges have demonstrated that social development is influenced by movement experiences, environmental interactions, parenting practices, empathy, and cognitive abilities (21-23). Similarly, movement-based interventions and play-oriented programs have been shown to promote social and psychological development in young children (24, 25). These findings support the notion that interventions targeting sensory-motor engagement and active participation may contribute substantially to social development and behavioral adaptation.

Another noteworthy implication concerns the relationship between behavioral regulation and social communication. Improvements in one domain may facilitate gains in the other. Children who experience

reduced behavioral difficulties may become more available for social interaction, learning, and communication. Conversely, enhanced social communication may reduce frustration, improve emotional regulation, and decrease maladaptive behaviors. Recent evidence highlighting the role of emotion regulation in social functioning among children with autism further supports this reciprocal relationship (2). Consequently, interventions that simultaneously address behavioral and social domains may generate mutually reinforcing developmental benefits.

The maintenance of treatment gains at follow-up further strengthens confidence in the effectiveness of both interventions. Sustained improvements suggest that the acquired skills and adaptive changes were not limited to the immediate intervention period but continued beyond treatment completion. The persistence of benefits may reflect the development of underlying competencies related to sensory regulation, attention control, motor coordination, and social engagement. Long-term maintenance is particularly important in autism interventions because enduring improvements are more likely to influence daily functioning, educational participation, and overall quality of life.

One limitation of the present study is the small sample size inherent in the single-case experimental design, which limits the generalizability of the findings to the broader population of children with Autism Spectrum Disorder. Additionally, the participants were recruited from a single specialized autism center and consisted only of children with severe functional limitations, which may restrict the applicability of the findings to children with different levels of functioning. Another limitation concerns the reliance on parent-reported measures for assessing behavioral problems and social communication, which may be influenced by subjective perceptions and expectations. Furthermore, the follow-up period was relatively short, preventing evaluation of the long-term sustainability of treatment effects over several months or years.

Future studies should examine these interventions using larger and more diverse samples drawn from multiple rehabilitation centers and geographical regions. Randomized controlled trials comparing vestibular-based therapy, smart interactive wall-assisted therapy, and combined intervention protocols would provide stronger evidence regarding their relative effectiveness. Researchers may also investigate the impact of these interventions on additional outcomes such as executive functioning, adaptive behavior, emotional regulation, quality of life, academic readiness, and family functioning. Longitudinal studies with extended follow-up periods are needed to determine the stability of treatment effects and identify factors that predict long-term success. Future investigations may also explore moderating variables such as age, symptom severity, cognitive functioning, and parental involvement.

From a practical perspective, the findings suggest that both vestibular processing improvement therapy and smart interactive wall-assisted therapy can be incorporated into comprehensive rehabilitation programs for children with Autism Spectrum Disorder. Rehabilitation centers, schools, and specialized clinics may benefit from integrating these interventions alongside existing therapeutic services. Clinicians should consider individual child characteristics, available resources, and family preferences when selecting intervention approaches. Training programs for therapists, educators, and parents may facilitate effective implementation and maximize treatment outcomes. The use of interactive technologies may be particularly valuable in settings seeking innovative and engaging therapeutic tools, whereas vestibular-based interventions may offer cost-effective options that can be adapted across a variety of rehabilitation contexts. Overall, both approaches appear capable of supporting meaningful improvements in behavioral functioning

and social communication among children with autism and may contribute to enhanced participation, independence, and quality of life.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

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

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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