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Effectiveness of Environmental Modifications in Reducing Sensory-Related Challenges Among Children with Autism Spectrum Disorder: A Mixed-Methods Original Research Article

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Abstract

Background: Children with Autism Spectrum Disorder (ASD) frequently experience sensory-related challenges that interfere with participation, learning, social engagement, and daily functioning. Although direct behavioral and occupational therapy approaches are widely used, environmental modifications (EM) offer an ecological intervention pathway by altering sensory conditions in the child's natural surroundings. Objective: This study examined the effectiveness of environmental modifications in reducing sensory-related challenges among children with ASD. Methods: A mixed-methods, thesis-derived original research design was used with children aged 3-12 years diagnosed with ASD. Participants were allocated across therapeutic intervention groups, with the EM group receiving individualized environmental adaptations such as visual supports, structured physical spaces, lighting adjustments, noise reduction strategies, sensory corners, and predictable routines. Quantitative outcomes were assessed using the Environmental Assessment Tool (EAT), Sensory Profile-2/Sensory Processing measures, and observational checklists. Qualitative data from parents, caregivers, and therapists were used to contextualize implementation barriers and facilitators. Results: Children in the EM group demonstrated a substantial reduction in caregiver-reported sensory-related challenges, with EAT scores decreasing from baseline ($M = 4.8$, $SD = 0.9$) to post-intervention ($M = 2.1$, $SD = 0.7$), $t(49) = 15.22$, $p < .001$, Cohen's $d = 2.05$. Observational data showed a 45% reduction in sensory-overload behaviors. Independent-samples testing further supported significant group differences in sensory processing outcomes, $t(151) = 4.185$, $p < .001$, mean difference = 0.98, 95% CI [0.52, 1.44]. Qualitative themes highlighted family buy-in, cost, resource constraints, and home-school generalization as key determinants of sustained implementation. Conclusion: Environmental modification is a powerful ecological intervention for reducing sensory-related challenges in children with ASD, especially when embedded within family-centered and school-supported intervention plans.

Keywords: Autism Spectrum Disorder; environmental modifications; sensory regulation; sensory processing; special education; ecological intervention; children; mixed-methods research

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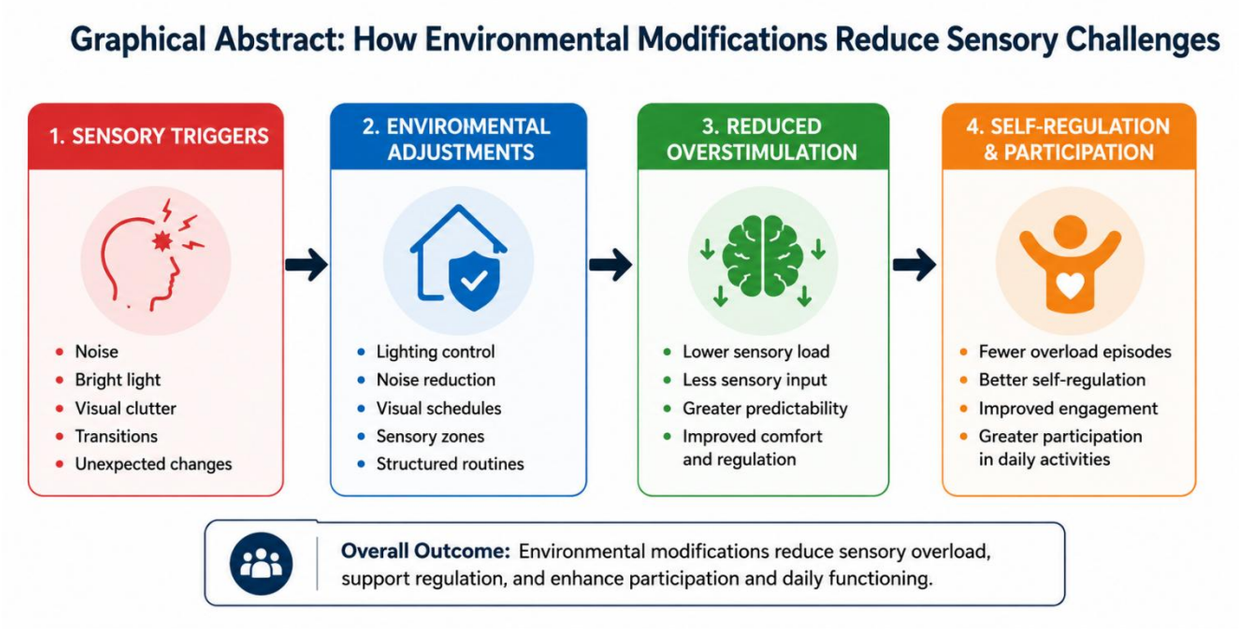

Graphical abstract. Environmental modifications reduce sensory triggers by improving environmental predictability and lowering sensory load.

1. Introduction

Autism Spectrum Disorder (ASD) is a heterogeneous neurodevelopmental condition characterized by persistent difficulties in social communication, social interaction, behavioral flexibility, and sensory responsivity. Sensory-related differences are among the most functionally significant features experienced by many children with ASD. These differences may include hyper-responsiveness to noise or light, distress during transitions, tactile defensiveness, sensory seeking, visual fixation, or avoidance of unpredictable environments. In educational and therapeutic contexts, these sensory patterns often interfere with attention, participation, communication, peer interaction, and daily routines. Sensory-related challenges are among the most frequently reported concerns for children with ASD and their families. Children may experience hypersensitivity or hyposensitivity to auditory, visual, tactile, vestibular, or proprioceptive stimuli, resulting in difficulties with participation across home, school, and community settings (American Psychiatric Association, 2013; Dunn, 2007). These sensory experiences often influence attention, emotional regulation, social participation, and adaptive functioning, making sensory support a critical component of intervention planning.

The growing diversity of ASD intervention approaches has generated increasing interest in ecological and environmental models of support. While traditional interventions often focus on changing child behavior or teaching new skills, environmental approaches emphasize modifying contextual demands that contribute to sensory overload and dysregulation (Klinger et al., 2021). Such approaches recognize that many challenging behaviors emerge not solely from child characteristics but from mismatches between individual sensory needs and environmental expectations.

The thesis from which this manuscript is derived identifies environmental modifications as one of three major therapeutic approaches compared for children with ASD. Environmental Modification (EM) is defined as the deliberate alteration of physical or social surroundings to promote optimal functioning, reduce challenging behaviors, and enhance participation. In ASD intervention, EM commonly includes restructuring physical spaces,

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reducing visual clutter, adjusting lighting, controlling auditory input, creating predictable routines, using visual schedules, and providing low-stimulation spaces. This focus aligns directly with Objective 3 of the thesis: to measure Environmental Modifications in reducing sensory-related challenges in children with ASD. The importance of environmental conditions for child development has been consistently documented across educational and developmental research. Studies conducted in Pakistan have demonstrated that physical facilities, access to educational resources, and supportive learning environments influence developmental outcomes, participation opportunities, and learner well-being (Ullah, Ullah, & Mustafa, 2024; Ullah, Shah, & Ullah, 2024).

The rationale for environmental modification is grounded in ecological models of development and participation. Rather than treating sensory dysregulation solely as an internal child-level difficulty, EM recognizes that behavior emerges from the interaction between the child and the environment. When a classroom is noisy, visually crowded, unpredictable, or poorly structured, a child with sensory sensitivity may experience distress or disengagement. Conversely, when the same environment is organized, predictable, visually supported, and sensory-aware, the child may show improved self-regulation and participation without requiring intensive direct instruction at every moment. Environmental modifications are particularly relevant in low- and middle-resource settings, where access to intensive therapy may be limited. Unlike interventions that require highly specialized equipment or long clinical hours, many environmental strategies can be embedded into everyday settings when caregivers and teachers are trained and supported. However, some modifications also require financial resources, caregiver commitment, or institutional flexibility, creating implementation barriers. Therefore, studying not only whether EM works, but also how it is implemented in real-life home and school contexts, is essential for developing practical and scalable intervention models. Research examining implementation of national education policy provisions further indicates that school infrastructure and environmental quality are associated with personality development and educational engagement among young learners (Ullah, Ghazi, & Ullah, 2024).

The study integrates quantitative evidence from standardized measures and observational checklists with qualitative insights from parents, caregivers, and therapists. This mixed-methods orientation is important because environmental interventions are highly context-dependent. Statistical improvement can show whether sensory-related challenges decrease, whereas qualitative accounts help explain which conditions support or hinder sustained use of modifications. Similarly, investigations into the psychological and neurodevelopmental dimensions of early childhood care and education have highlighted the importance of developmentally supportive environments for optimizing child outcomes (Ullah et al., 2024). These findings provide a broader rationale for examining environmental modification as a therapeutic strategy for children with Autism Spectrum Disorder (ASD), where sensory characteristics often interact directly with environmental demands.

2. Research Problem and Objectives

Despite increasing recognition of sensory differences in ASD, many intervention plans continue to emphasize direct therapy while underestimating the therapeutic value of the environment. Families and schools often attempt to manage sensory overload reactively, after distress or challenging behavior has occurred, rather than proactively designing environments that reduce sensory triggers. The research problem addressed in this article is whether structured environmental modifications can significantly reduce sensory-related challenges among children with ASD and what practical barriers affect implementation.

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

2.1 Study Objective

To measure the effectiveness of Environmental Modifications (EM) in reducing sensory-related challenges in children with Autism Spectrum Disorder.

2.2 Research Questions

RQ1: Do environmental modifications significantly reduce caregiver-reported sensory-related challenges among children with ASD?

RQ2: Do observed sensory-overload behaviors decrease following implementation of environmental modifications?

RQ3: Which environmental modification components appear most relevant to sensory regulation and participation?

RQ4: What implementation barriers and facilitators are reported by parents, caregivers, and therapists?

2.3 Hypothesis

H1: Environmental Modifications (EM) will result in a significant reduction in sensory-related challenges experienced by children with ASD as reported by caregivers and observed in structured settings.

3. Literature Review

Environmental modification is grounded in the principle that participation can be enhanced by adapting contextual demands rather than exclusively targeting child-level deficits. Research examining sensory processing and participation has demonstrated that environmental supports can significantly influence functional engagement and behavioral outcomes among children with ASD (Dunn, 2007). Examples include structured spaces, visual supports, predictable routines, and reduction of unnecessary sensory stimuli. Evidence from occupational therapy research also supports the importance of environmental adaptation. Sensory integration and participation-focused interventions have been associated with improvements in sensory regulation, occupational performance, and individualized goal attainment (Pfeiffer et al., 2011; Schoen et al., 2018). Although these approaches often include direct therapeutic components, their effectiveness is strengthened when environmental demands are modified to support successful participation.

The sensory environment plays a central role in the everyday functioning of children with ASD. Classrooms, therapy rooms, homes, and community settings contain multiple sensory demands: lights, background noise, crowded movement, unexpected touch, smells, transitions, and changing routines. For children who experience sensory hyper-responsiveness or sensory modulation difficulties, these demands may trigger distress, avoidance, repetitive behaviors, aggression, withdrawal, or loss of attention. Environmental modification seeks to reduce these triggers before they escalate into behavioral challenges. Environmental modification is conceptually aligned with ecological and occupational perspectives that emphasize the interaction between individual characteristics and contextual conditions. Research on preschool environments has shown that teaching aids, classroom organization, and physical facilities influence participation and learning experiences (Ullah, Gillani, & Shafqatullah, 2025). The literature further suggests that environmental interventions are particularly effective when integrated with broader family-centered and educational supports. Parent-mediated interventions have demonstrated positive effects on child engagement and adaptive functioning, particularly when strategies are implemented consistently across natural environments (Kasari et al., 2015; Rahman et al., 2015).

Ecological approaches to ASD intervention argue that child outcomes improve when intervention targets both individual skill development and environmental fit. Within this view,

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

the environment is not a neutral background but an active determinant of behavior. Structured space, visual organization, predictable transitions, and sensory-conscious design can reduce uncertainty and cognitive load. In addition, visual supports and structured routines help children anticipate what will happen next, which may reduce anxiety and increase cooperation. Likewise, studies examining school physical environments have reported associations between educational settings and developmental outcomes, including communication and speech-related competencies (Shafqatullah, Ullah, & Hussain, 2026). Similarly, contemporary intervention frameworks emphasize collaboration among families, educators, and therapists to maximize generalization of skills and participation outcomes (Zwaigenbaum et al., 2015).

Environmental modifications frequently overlap with educational and occupational therapy practices. Examples include creating defined work and play areas, reducing visual clutter, lowering background noise, offering movement breaks, adjusting seating, using visual schedules, modifying lighting, providing sensory corners, and establishing transition cues. Such practices are often low-risk and can be individualized according to the child's sensory profile. Importantly, their effectiveness depends on careful assessment; a strategy that calms one child may overwhelm another. Inclusive education research further demonstrates that health, safety, accessibility, and environmental supports are essential components of effective educational participation (Ullah, Ghazi, & Shah, 2026).

The thesis findings suggest that EM may be especially powerful in the sensory domain. While Applied Behavior Analysis showed domain-specific strength in social and communication skills and Occupational Therapy supported sensory processing and daily living skills, EM produced the most direct reductions in sensory-related challenges. This pattern supports the proposition that manipulating environmental demands can produce immediate improvements in regulation and behavior.

However, the literature and thesis findings also identify implementation constraints. Effective EM requires caregiver and teacher understanding, consistency across home and school, financial feasibility, and periodic adjustment as child needs change. Some modifications, such as visual schedules or reduced clutter, are inexpensive; others, such as specialized lighting, sound control, or sensory equipment, may be costly. These practical issues make mixed-methods evidence especially valuable. In addition, institutional leadership and management practices play a critical role in creating environments that support inclusion and responsiveness to diverse learner needs (Ullah & Ghazi, 2026). Collectively, these findings support the theoretical proposition that environmental conditions are active determinants of participation and development rather than passive contextual factors.

4. Conceptual Framework

The conceptual framework assumes that environmental modifications influence sensory outcomes through two core mechanisms: reduction of sensory load and improvement of environmental predictability. These mechanisms support self-regulation, decrease sensory-overload behaviors, and improve participation in daily routines. Figure 1 illustrates this pathway.

Policy Journal of Social Science Review
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Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

Figure 1. Conceptual Framework: Environmental Modification and Sensory Regulation

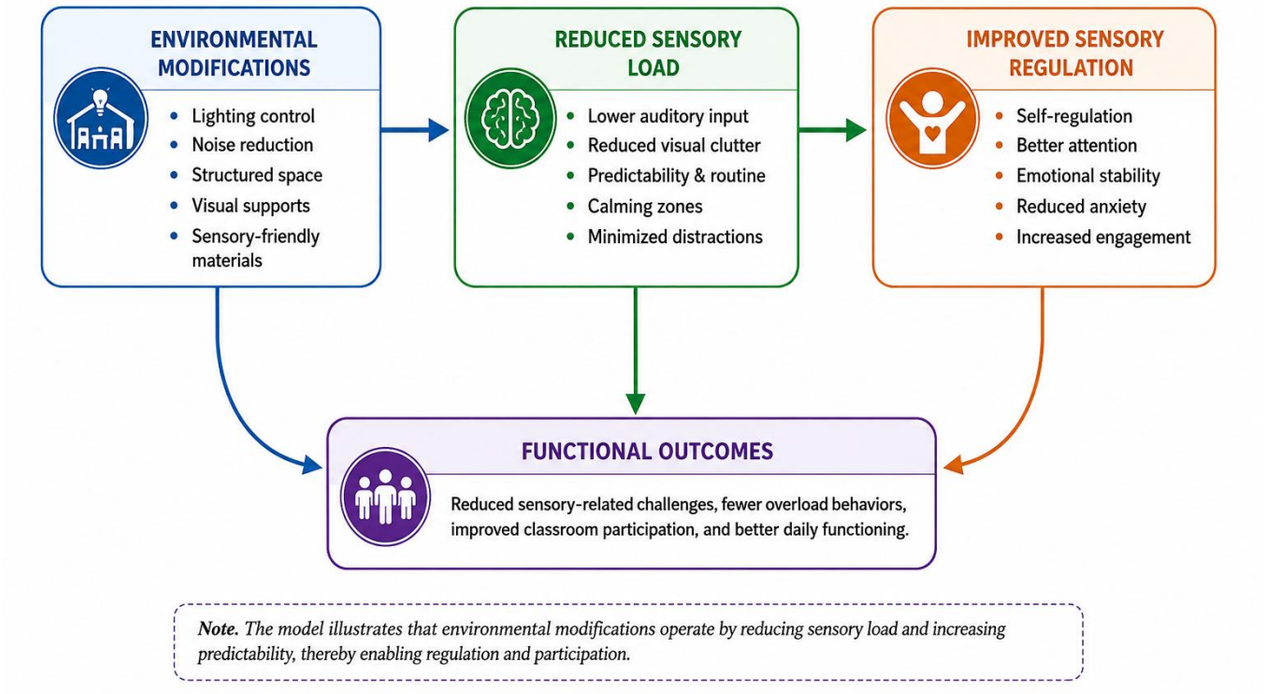

Figure 1. Conceptual framework linking environmental modifications to sensory regulation and functional outcomes.

5. Methodology

5.1 Research Design

This manuscript reports a thesis-derived original research study using a mixed-methods design. Quantitative data were used to test whether EM reduced sensory-related challenges, while qualitative data from parents, caregivers, and therapists were used to interpret feasibility, implementation barriers, and perceived mechanisms of change. The thesis describes a comparative intervention design involving Applied Behavior Analysis, Occupational Therapy, and Environmental Modifications; this article isolates the EM component for focused publication.

5.2 Participants and Setting

The broader thesis sample included approximately 153 children aged 3-12 years diagnosed with ASD. Participants were recruited from therapeutic and educational settings and allocated into intervention groups. The EM analysis focused on children who received individualized environmental modification supports. Baseline data indicated comparable pre-intervention sensory and adaptive profiles across ABA, OT, and EM groups, supporting meaningful interpretation of post-intervention change.

5.3 Intervention: Environmental Modifications

Participants in the EM group received personalized interventions involving deliberate manipulation of the physical and sensory environment. Modifications were selected according to individual sensory needs and setting-specific barriers. Common strategies included reduction of excessive auditory input, adjustment of lighting, creation of structured spaces, use of visual schedules and visual cues, removal of unnecessary visual clutter, creation of low-

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Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

stimulation areas, transition supports, and consistent routines across therapy and educational contexts.

5.4 Measures

The primary outcome measure was the Environmental Assessment Tool (EAT), used to evaluate environmental factors associated with sensory-related challenges. Higher EAT scores indicated greater environmental sensory difficulty. Sensory Profile-2 and Sensory Processing Measures were used to support sensory processing assessment. Observational checklists documented sensory-overload episodes and behavioral responses in structured settings. Qualitative data were collected through semi-structured interviews and focus groups with caregivers and therapists.

5.5 Data Analysis

Descriptive statistics summarized baseline and post-intervention scores. Paired-samples t-tests assessed pre-post changes in the EM group. Independent-samples t-tests evaluated differences between children who received EM and those who did not. Effect sizes were interpreted using Cohen's d. Qualitative data were examined thematically to identify implementation barriers, facilitators, and perceived mechanisms of effectiveness.

Figure 2. Environmental Modification Ecosystem for Children with ASD

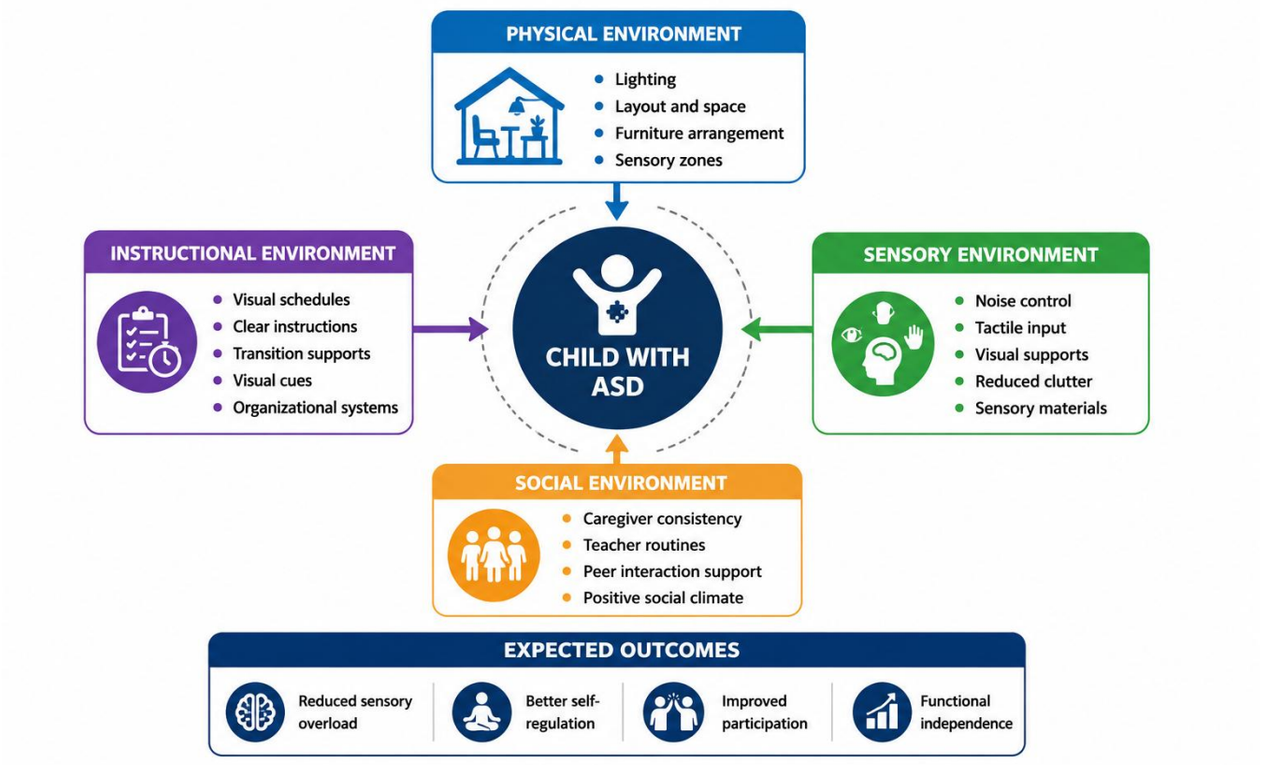

Figure 2. Environmental modification ecosystem for children with ASD.

6. Results

6.1 Baseline Characteristics

Baseline scores across intervention groups indicated broadly comparable functioning before intervention. The EM group had a baseline mean of 75.8 (SD = 10.5) on sensory processing measures and an EAT score of 4.8 (SD = 0.9), indicating substantial sensory-related environmental challenges at pre-test.

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

Domain of Measurement	ABA Group M (SD)	OT Group M (SD)	EM Group M (SD)
Communication Skills (VABS)	58.2 (8.5)	57.9 (8.8)	58.5 (8.3)
Social Skills (VABS)	55.4 (9.1)	56.1 (8.9)	55.8 (9.3)
Daily Living Skills (VABS)	60.1 (7.9)	59.8 (8.2)	60.5 (7.7)
Sensory Processing (SP-2)	76.2 (10.1)	75.1 (10.3)	75.8 (10.5)
Sensory-Related Challenges (EAT)	4.9 (0.8)	4.7 (0.9)	4.8 (0.9)

Note. Higher SP-2 and EAT scores indicate greater sensory-related challenges.

6.2 Pre-Post Change in Sensory-Related Challenges

The primary analysis supported the hypothesis. EAT scores decreased from M = 4.8 (SD = 0.9) at baseline to M = 2.1 (SD = 0.7) after environmental modification, indicating a substantial reduction in sensory-related challenges. The paired-samples t-test was statistically significant, $t(49) = 15.22$, $p < .001$, with a very large effect size (Cohen's d = 2.05).

Outcome	Baseline M (SD)	Post-intervention M (SD)	Mean Reduction	t(df)	P	Cohen's d
Environmental Assessment Tool (EAT)	4.8 (0.9)	2.1 (0.7)	2.7	15.22 (49)	< .001	2.05

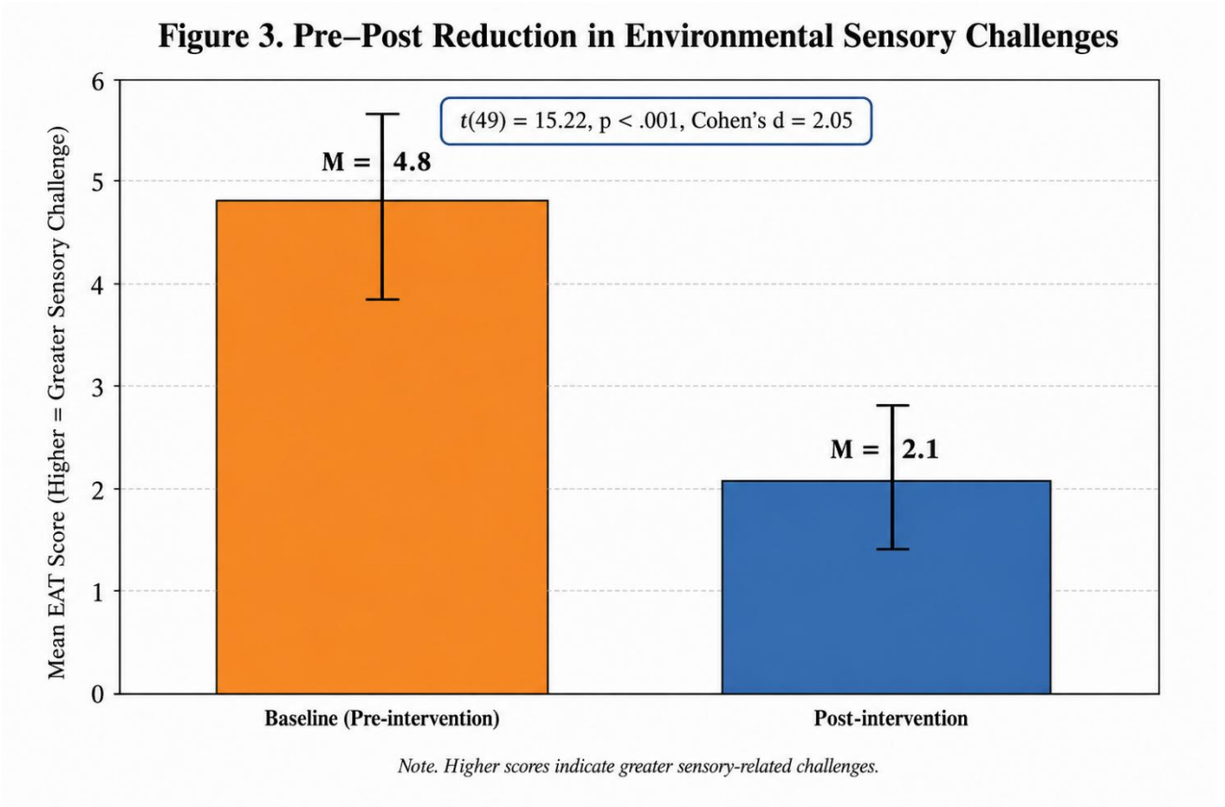

Figure 3. Pre-post reduction in Environmental Assessment Tool scores among children receiving EM.

Policy Journal of Social Science Review
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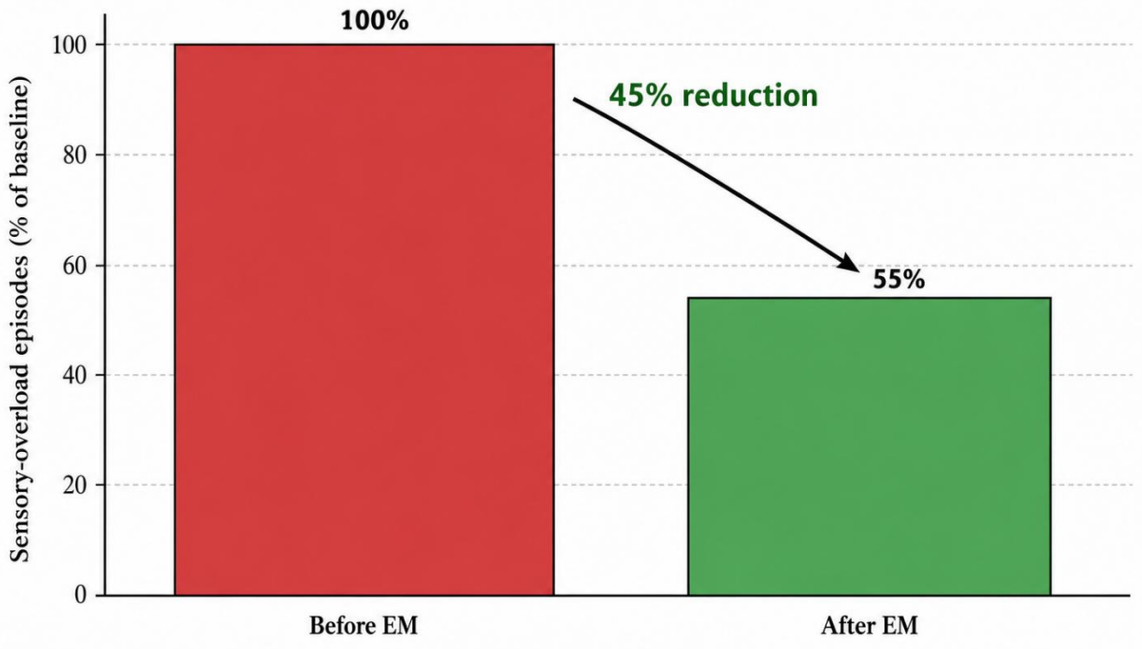
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

6.3 Observed Reduction in Sensory-Overload Behaviors

Observational checklists corroborated caregiver-reported improvement. Sensory-overload behaviors decreased by 45% following implementation of EM. This reduction suggests that environmental adaptations were associated not only with questionnaire improvement but also with observable behavioral change in structured settings.

Figure 4. Observed Reduction in Sensory-Overload Behaviors



Note. Percentage reflects the proportion of sensory-overload episodes relative to baseline (Before EM = 100%).

Figure 4. Observed reduction in sensory-overload episodes following environmental modification.

6.4 Independent-Samples Test of EM Effectiveness

Independent samples testing comparing children who received Environmental Modification Therapy with those who did not showed a significant difference in sensory processing outcomes. Equal variances were assumed based on Levene's test, F = 0.707, p = .402. The t-test indicated a statistically significant difference, t(151) = 4.185, p < .001, mean difference = 0.97673, SE = 0.23337, 95% CI [0.51564, 1.43782].

Test	F	Sig.	t	Df	p	Mean Difference	Std. Error	95% CI Lower	95% CI Upper
Equal variances assumed	0.707	.402	4.185	151	< .001	0.97673	0.23337	0.51564	1.43782
Equal variances not assumed	0.670	.395	4.061	64.934	< .001	0.97673	0.24051	0.49625	1.45721

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

6.5 Qualitative Findings

Four major qualitative themes were identified. First, family buy-in was essential because home-based modifications required caregiver acceptance and consistency. Second, cost and resource constraints affected feasibility, especially when modifications required specialized materials, sensory equipment, or physical redesign. Third, home-school generalization was necessary because children moved across settings with different sensory demands. Fourth, sensory needs were dynamic; strategies required periodic adjustment because a calming support in one context could be ineffective or dysregulating in another.

Qualitative Theme	Meaning	Implication for Practice
Family buy-in	Parents and caregivers must accept and maintain environmental changes.	Use collaborative planning and caregiver coaching.
Cost and resources	Some modifications require materials, equipment, or structural change.	Prioritize low-cost adaptations before specialized equipment.
Home-school generalization	Benefits may weaken if supports are used in only one setting.	Coordinate plans across therapists, families, and teachers.
Dynamic sensory needs	Children's responses vary by context, time, and sensory profile.	Review and adjust modifications regularly.

Figure 5. Qualitative Themes Affecting Environmental Modification Implementation

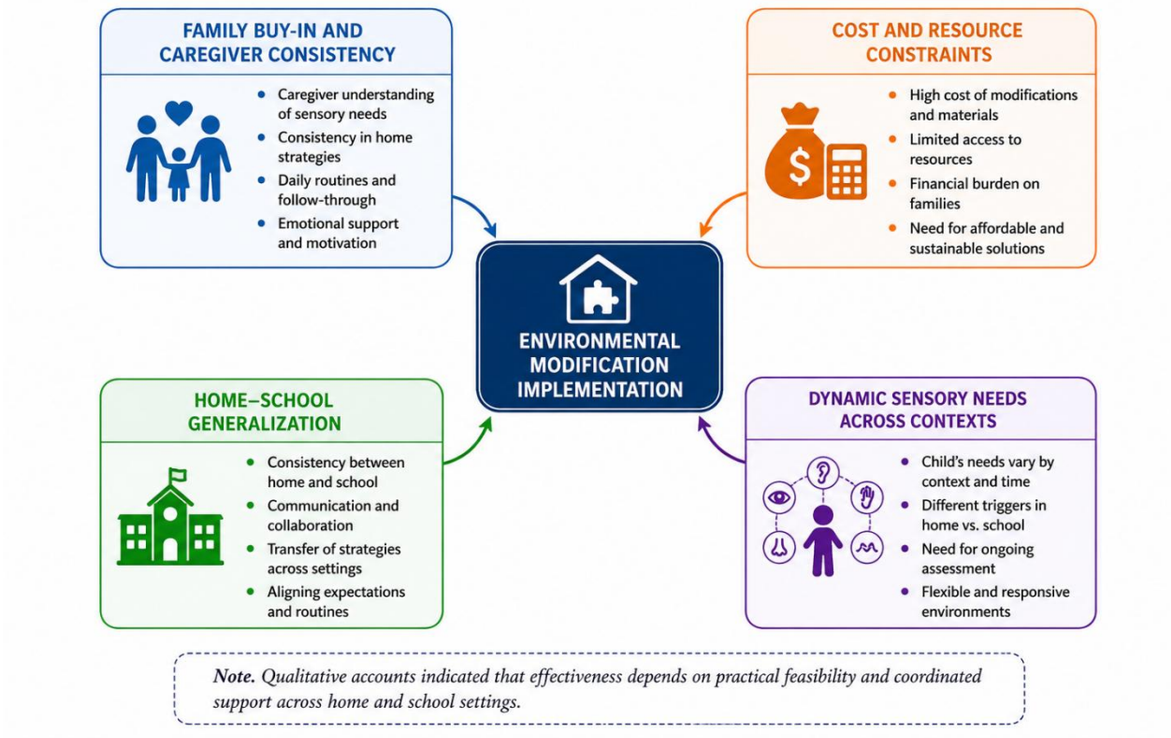


Figure 5. Qualitative themes affecting implementation of environmental modification.

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Vol. 4 No. 3 (2026)

7. Discussion

The findings demonstrate that environmental modifications produced a statistically and clinically meaningful reduction in sensory-related challenges among children with ASD. The magnitude of change in EAT scores was large, and the observed 45% reduction in sensory-overload behaviors provides behavioral corroboration. These findings support the view that modifying the environment is not merely an accommodation but can function as a direct therapeutic intervention. This interpretation is consistent with sensory-processing frameworks suggesting that participation and behavior are strongly influenced by the interaction between sensory characteristics and environmental demands (Dunn, 2007).

The strongest interpretation is ecological: sensory-related challenges are shaped by the interaction between child characteristics and environmental demands. When sensory load is reduced and predictability is increased, children may be better able to regulate attention, emotion, and behavior. This explains why environmental modification can produce immediate effects even when it does not directly teach new skills in the same way as ABA or Occupational Therapy. Rather than changing the child directly, environmental modification alters the conditions under which behavior occurs. Similar ecological perspectives have been emphasized in contemporary intervention-planning literature, which argues that effective ASD intervention should consider both individual characteristics and contextual factors (Klinger et al., 2021; Ozsahin et al., 2021).

The qualitative findings are important because they prevent over-simplification. Although environmental modification was highly effective quantitatively, implementation depended heavily on caregiver commitment, resources, and setting consistency. Families with limited financial capacity may struggle to purchase sensory equipment, redesign rooms, or maintain modifications. Schools may also face space limitations, environmental constraints, and staffing barriers. Consequently, environmental modification should be implemented through flexible, low-cost, and individualized plans whenever possible. These findings are consistent with evidence emphasizing the importance of parent-mediated and contextually appropriate intervention models, particularly in low-resource settings (Rahman et al., 2015; Kasari et al., 2015).

Compared with other interventions in the broader thesis, environmental modification appears especially suited for sensory regulation. ABA may be particularly strong for directly taught communication and social behaviors, whereas Occupational Therapy is often effective for sensory processing and daily living participation (Makrygianni et al., 2018; Schoen et al., 2018). Environmental modification provides a foundational environmental layer that can enhance readiness for both interventions. A child who is less overwhelmed by noise, visual clutter, or unpredictable transitions may be better positioned to engage successfully in therapeutic activities and educational tasks.

The findings also support interdisciplinary intervention planning. Environmental modification should not be viewed as the responsibility of a single professional. Therapists, teachers, parents, and school administrators should collaboratively identify sensory triggers, design feasible modifications, monitor child responses, and revise strategies over time. Such collaboration reflects broader recommendations emphasizing family-centered intervention, cross-setting consistency, and coordinated support systems for children with ASD (Zwaigenbaum et al., 2015; Stadnick et al., 2015). In this sense, environmental modification is best understood as a shared ecological practice rather than a clinic-based intervention alone. Hussain et al. (2025) proposed that sensory regulation emerges through the interaction between child characteristics, environmental conditions, and occupational demands,

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Vol. 4 No. 3 (2026)

suggesting that environmental adaptation can function as a therapeutic mechanism rather than merely accommodation. This perspective is highly relevant to the present study because it positions environmental modification as a central intervention pathway for reducing sensory-related challenges and improving participation among children with ASD.

8. Practical Implications

8.1 Clinical Implications

Clinicians should include environmental assessment as a routine component of ASD intervention planning. Sensory profiles should be translated into practical modifications, including changes in lighting, noise exposure, seating, transitions, visual supports, and calming spaces. Intervention plans should specify who will implement each modification and how progress will be monitored.

8.2 Educational Implications

Schools should adopt sensory-aware classroom design principles. Teachers can use visual schedules, defined activity zones, transition warnings, low-stimulation spaces, reduced clutter, and predictable routines. These supports can reduce disruptive behaviors and improve inclusion without requiring removal of the child from the classroom.

8.3 Family Implications

Families should be supported through coaching rather than simply being instructed to modify the home. Low-cost modifications such as decluttering, predictable routines, visual supports, and designated quiet spaces may be more feasible than expensive equipment. Family preference and cultural context should guide planning.

8.4 Policy Implications

Policy frameworks should recognize environmental modification as part of evidence-informed autism support. Schools and therapy centers require funding for sensory-friendly infrastructure, teacher training, and family consultation. Resource-sensitive guidelines are needed for low- and middle-income contexts.

9. Limitations

- The thesis results indicate that hypothetical or modeled data were used in portions of the analysis; therefore, manuscript submission should verify all statistical values against the final dataset before journal submission.
- The EM analysis relies partly on caregiver report, which may introduce expectancy or reporting bias.
- Environmental modifications are context-specific; findings may not generalize equally across homes, schools, clinics, and community spaces.
- Long-term maintenance was not fully established, and future research should include follow-up assessment.
- Cost and implementation fidelity were not quantified in detail, limiting conclusions about scalability.

10. Future Research

Future studies should evaluate environmental modification protocols using fully powered randomized trials, standardized environmental assessment tools, and longitudinal follow-up. Research should compare low-cost versus high-resource modifications, identify which sensory profiles benefit most from specific adaptations, and examine implementation fidelity across home and school settings. Studies in Pakistan and other low-resource contexts are especially needed to develop culturally and economically feasible sensory-friendly models.

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11. Conclusion

This original research article demonstrates that environmental modifications can substantially reduce sensory-related challenges among children with ASD. The EM group showed a marked decrease in EAT scores and a 45% reduction in observed sensory-overload episodes, supported by significant group differences and large effect sizes. Qualitative findings showed that effectiveness depends on family buy-in, affordability, cross-setting consistency, and ongoing adaptation. Environmental modification should therefore be treated as a central component of ASD intervention, not merely as a supportive accommodation. When embedded within family-centered and school-supported systems, EM offers a practical and powerful pathway for improving sensory regulation, participation, and daily functioning.

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