

RECONCEPTUALIZING SENSORY REGULATION IN AUTISM SPECTRUM DISORDER: A COMPARATIVE AND INTEGRATIVE ANALYSIS OF OCCUPATIONAL THERAPY AND ENVIRONMENTAL MODIFICATIONS

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Abstract

Sensory processing differences constitute a central and functionally significant dimension of Autism Spectrum Disorder (ASD), shaping children's behavioural regulation, participation, and adaptive functioning. Despite extensive use of Occupational Therapy (OT) and Environmental Modifications (EM) to address these challenges, existing research has largely examined these approaches in isolation, limiting understanding of their comparative and integrative effects. This study investigates the differential and complementary efficacy of OT and EM through a mixed-methods randomized controlled design with longitudinal follow-up involving children aged 3–12 years diagnosed with ASD. Quantitative findings indicate that OT produces significant improvements in sensory integration, adaptive functioning, and participation through individualized, activity-based interventions. In contrast, EM contributes to immediate reductions in sensory overload and behavioural dysregulation by restructuring environmental demands. However, the most substantial and sustained outcomes emerge from the alignment of these approaches, highlighting their complementary mechanisms. Qualitative analysis further reveals that intervention effectiveness is shaped by contextual and systemic factors, including socioeconomic conditions, implementation barriers, and the congruence between professional practices and family experiences. Drawing on a person environment interaction perspective, the study reconceptualizes sensory regulation as a dynamic, relational process rather than a solely intrinsic deficit. It advances an integrative framework in which optimal outcomes are achieved through the alignment of internal regulatory capacities and external environmental supports. The findings contribute to intervention science by bridging the gap between clinical efficacy and real-world applicability, offering implications for practice, interdisciplinary collaboration, and policy development in autism care.

Keywords: Autism Spectrum Disorder; Sensory Regulation; Occupational Therapy; Environmental Modifications; Person–Environment Interaction; Mixed-Methods Research

INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex and heterogeneous neurodevelopmental condition characterized by persistent deficits in social communication and the presence of restricted, repetitive patterns of behaviour. Among its most pervasive and functionally significant features are atypical sensory processing patterns, which influence how individuals perceive, interpret, and respond to environmental stimuli. These sensory differences—ranging from hypersensitivity and hyposensitivity to sensory-seeking behaviours—are not peripheral symptoms but central mechanisms that shape behavioural regulation, emotional responses, and participation in daily life (Ben-Sasson et al., 2009; Dunn, 2007). Consequently, sensory regulation has emerged as a critical domain in both clinical intervention and educational practice for children with ASD.

Children with ASD frequently experience difficulties in navigating everyday environments due to sensory overload or under-responsiveness, leading to behavioral dysregulation, withdrawal, and challenges in academic and social participation. These challenges are further compounded by contextual and environmental conditions, particularly in educational settings where physical infrastructure, teaching resources, and environmental design significantly influence developmental outcomes. Research in broader educational contexts has demonstrated that

physical facilities, learning environments, and resource availability play a crucial role in shaping children's cognitive, behavioural, and personality development (Ullah et al., 2024a; Ullah et al., 2025). These findings highlight the importance of considering environmental conditions not merely as background variables but as active determinants of developmental functioning, particularly for children with neurodevelopmental differences.

Despite growing recognition of sensory challenges in ASD, intervention research remains fragmented. Existing studies predominantly examine therapeutic approaches in isolation, focusing either on individual-centered interventions or environmental adjustments without adequately addressing their interaction. Occupational Therapy (OT) and Environmental Modifications (EM) represent two prominent yet fundamentally distinct paradigms within this landscape. OT emphasizes individualized, activity-based interventions aimed at enhancing internal sensory processing, adaptive functioning, and self-regulation capacities (Schaaf et al., 2014). In contrast, EM targets external conditions by modifying environmental stimuli—such as noise levels, lighting, and spatial organization—to reduce sensory overload and facilitate engagement (Ashburner et al., 2008).

This dichotomy reflects a broader theoretical divide between individual-centered and context-centered models of intervention. However, contemporary developmental perspectives suggest that sensory experiences do not occur solely within the individual but emerge through continuous interaction between the individual and their environment (Bronfenbrenner, 1979; Law et al., 1996). In this regard, the effectiveness of any intervention cannot be fully understood without considering the alignment or misalignment between internal capacities and environmental demands.

Statement of the Problem

Although both Occupational Therapy and Environmental Modifications have demonstrated effectiveness in addressing sensory-related challenges in children with ASD, the literature lacks a comprehensive understanding of their comparative and integrative impact. Most existing studies adopt a reductionist approach by evaluating interventions in isolation, thereby neglecting the dynamic interaction between individual and environmental factors. This gap is particularly critical in contexts where environmental conditions, resource availability, and systemic constraints significantly influence intervention outcomes (Ullah et al., 2024c; Ullah et al., 2026a).

Furthermore, limited attention has been given to how these interventions function within real-world settings, where socioeconomic disparities, institutional barriers, and variations in physical environments affect implementation and effectiveness. Studies examining educational infrastructure, health and safety standards, and inclusive practices suggest that environmental and systemic conditions play a decisive role in shaping developmental outcomes (Ullah et al., 2026b; Shafqatullah et al., 2026). However, these insights have not been sufficiently integrated into intervention models for ASD.

Purpose and Contribution of the Study

In response to these gaps, the present study investigates the differential and complementary efficacy of Occupational Therapy and Environmental Modifications in addressing sensory regulation among children with ASD. More importantly, it advances a conceptual shift by proposing an integrative framework that reconceptualizes sensory challenges as emerging from person–environment interactions rather than as solely intrinsic deficits.

By bridging individual-centered and context-centered approaches, the study contributes to intervention science in three significant ways. First, it provides empirical evidence on the comparative effectiveness of OT and EM. Second, it highlights the role of contextual and systemic factors in shaping intervention outcomes. Third, it develops a theoretically grounded conceptual framework that supports a more holistic and interaction-based understanding of sensory regulation in ASD.

LITERATURE REVIEW

Sensory Processing as a Core Dimension of Autism Spectrum Disorder

Sensory processing differences are now widely recognized as a defining and functionally significant dimension of Autism Spectrum Disorder (ASD), influencing behavioural regulation, emotional responses, and participation in everyday activities. Children with ASD frequently experience hypersensitivity, hyposensitivity, or sensory-seeking behaviours, which affect their ability to interpret and respond appropriately to environmental stimuli (Ben-Sasson et al., 2009; Dunn, 2007; Ullah et al., 2024a). These sensory challenges often manifest in difficulties with attention, social interaction, and adaptive functioning, making sensory regulation a central focus of intervention research.

Traditional perspectives have largely conceptualized sensory processing difficulties as intrinsic neurological deficits. While such models have contributed to the development of targeted therapeutic interventions, they tend to overlook the role of environmental conditions in shaping sensory experiences. Emerging research increasingly emphasizes that sensory functioning is not solely an internal process but is influenced by the interaction between individual sensory profiles and environmental demands (Bronfenbrenner, 1979; Law et al., 1996). In educational contexts, this interaction becomes particularly critical, as physical infrastructure, classroom organization, and resource availability directly affect children's engagement and developmental outcomes. Studies examining educational environments have demonstrated that physical facilities and contextual conditions significantly

influence children's behavioural and personality development, highlighting the importance of environmental factors in shaping learning experiences (Ullah et al., 2024b; Ullah et al., 2025).

Occupational Therapy and the Enhancement of Internal Sensory Regulation

Occupational Therapy (OT) has emerged as a central intervention for addressing sensory processing challenges in children with ASD, particularly through sensory integration approaches that aim to improve the brain's ability to organize and respond to sensory input. OT adopts a client-centered perspective, focusing on enhancing adaptive functioning, motor coordination, and participation in meaningful daily activities (Schaaf et al., 2014). Through structured, individualized, and activity-based interventions, children are gradually supported in developing more appropriate and regulated responses to sensory stimuli.

Empirical evidence suggests that OT contributes to improvements in sensory modulation, behavioural regulation, and participation in daily routines. By targeting internal sensory processing mechanisms, OT facilitates long-term skill development and functional independence. However, the effectiveness of OT is influenced by multiple factors, including the intensity and duration of intervention, therapist expertise, and the heterogeneity of sensory profiles among children with ASD. Moreover, while OT strengthens internal capacities, it may not fully address the environmental conditions that continue to impose sensory demands on the child.

This limitation becomes particularly relevant in educational and developmental contexts where environmental factors, such as classroom design, availability of teaching aids, and institutional resources, significantly influence learning outcomes. Research in early childhood and school environments indicates that physical facilities and instructional supports play a crucial role in shaping children's developmental trajectories and engagement (Ullah et al., 2024c; Ullah et al., 2024d). These findings suggest that interventions focused solely on internal regulation may be insufficient without corresponding environmental adjustments.

Environmental Modifications and the Restructuring of Contextual Demands

Environmental Modifications (EM) represent a complementary intervention approach that focuses on altering physical and social environments to reduce sensory stressors and enhance functional engagement. These modifications may include adjustments to lighting, sound levels, spatial organization, and the use of visual supports and structured routines to create predictable and supportive environments for children with ASD (Ashburner et al., 2008).

Unlike OT, which targets internal sensory processing, EM operates at the contextual level by aligning environmental conditions with the child's sensory needs. Research indicates that EM is effective in reducing sensory overload, minimizing behavioural dysregulation, and improving attention and participation in educational and social settings. These benefits are particularly evident in structured environments where sensory demands can be systematically controlled.

However, while EM provides immediate functional improvements, it does not directly enhance the child's intrinsic sensory processing abilities. This raises important questions regarding the sustainability of outcomes when environmental supports are removed or altered. Furthermore, the effectiveness of EM is closely linked to broader systemic and infrastructural factors, including resource availability, institutional support, and policy implementation. Studies examining inclusive education and school environments highlight that health, safety, and physical infrastructure play a decisive role in shaping developmental and behavioural outcomes (Ullah et al., 2026a; Ullah & Ghazi, 2026). These findings reinforce the need to consider environmental and systemic conditions as integral components of intervention effectiveness.

Theoretical Gap: Toward an Interaction-Based Model of Sensory Regulation

Despite substantial evidence supporting both Occupational Therapy and Environmental Modifications, a critical limitation in the literature is the tendency to examine these approaches in isolation. This separation reflects a broader divide between individual-centered and context-centered models of intervention, resulting in fragmented understandings of sensory regulation in ASD. Existing research rarely explores how these approaches interact or how their integration may produce more comprehensive and sustainable outcomes.

This study addresses this gap by adopting a person–environment interaction framework, which posits that sensory regulation emerges from the dynamic alignment between individual capacities and environmental demands (Law et al., 1996; Bronfenbrenner, 1979). From this perspective, sensory challenges are not solely intrinsic deficits but are relational phenomena shaped by continuous interaction between the child and their environment.

By integrating insights from both intervention paradigms and contextual research, this study advances a more holistic understanding of sensory regulation. It proposes that optimal outcomes are achieved not through isolated interventions but through the alignment of internal sensory capacities and external environmental supports. This interaction-based approach provides a conceptual foundation for developing integrated intervention models that are both theoretically robust and practically applicable in diverse educational and clinical settings.

METHODOLOGY

Research Design

This study employed a mixed-methods randomized controlled design with longitudinal follow-up to examine the comparative and integrative effectiveness of Occupational Therapy (OT) and Environmental Modifications (EM) in addressing sensory regulation among children with Autism Spectrum Disorder (ASD). The use of a mixed-methods approach was guided by the need to capture both measurable intervention outcomes and the contextual, experiential, and systemic dimensions influencing their effectiveness. Such an approach is particularly appropriate for complex developmental phenomena, where quantitative measures alone may fail to reflect real-world variability and lived experiences (Creswell & Plano Clark, 2017).

The randomized controlled structure enhances internal validity by enabling systematic comparison between intervention groups, while the longitudinal component allows for the assessment of both immediate and sustained effects. The integration of quantitative and qualitative data further supports a comprehensive understanding of sensory regulation as a dynamic and interaction-based process.

Population and Sample

The population for this study consisted of children diagnosed with Autism Spectrum Disorder, along with key stakeholders involved in their care and intervention processes, including therapists, educators, and parents. A sample of 150 children aged between 3 and 12 years was selected to represent a developmental range in which sensory processing and adaptive functioning are particularly salient.

A purposive sampling strategy was employed to ensure the inclusion of participants with diverse cognitive, sensory, and socioeconomic profiles. This diversity was essential for capturing variability in intervention responsiveness and contextual influences. In addition, caregivers and professionals were included to provide complementary perspectives on intervention implementation and outcomes, thereby enhancing the credibility and depth of qualitative findings (Patton, 2015).

Intervention Design

Participants were randomly assigned to one of two intervention groups: an Occupational Therapy (OT) group and an Environmental Modifications (EM) group. The OT group received individualized, activity-based interventions designed to enhance sensory integration, adaptive functioning, and self-regulation. These interventions were implemented by trained professionals using structured therapeutic protocols aligned with sensory integration principles.

The EM group, in contrast, received interventions focused on modifying environmental conditions to reduce sensory stressors and facilitate engagement. These modifications included adjustments to physical settings, sensory stimuli, and routine structures to align environmental demands with the child's sensory profile.

The comparative design allowed for the examination of both the differential effects of each intervention and their broader implications within a person–environment interaction framework.

Data Collection Methods

Data were collected using a combination of standardized assessments and qualitative interviews to ensure methodological triangulation. Quantitative data were obtained through validated sensory processing measures and adaptive behavior scales, which assessed changes in sensory regulation, functional performance, and participation. Qualitative data were collected through semi-structured interviews with caregivers and professionals. These interviews explored participants' experiences, perceptions of intervention effectiveness, and contextual challenges related to implementation. The use of semi-structured formats ensured consistency across interviews while allowing flexibility to capture nuanced and context-specific insights.

Procedure

The study was conducted in multiple phases. Initially, participants were recruited, and informed consent was obtained from caregivers and relevant stakeholders. Baseline assessments were conducted to establish initial levels of sensory processing and adaptive functioning.

Following baseline evaluation, interventions were implemented over a defined period, with each group receiving its respective treatment protocol. Data collection occurred at multiple time points to capture both immediate and longitudinal effects of interventions. Qualitative interviews were conducted concurrently to document ongoing experiences and contextual influences.

This iterative procedure enabled the integration of quantitative outcomes with qualitative insights, supporting a comprehensive understanding of intervention effectiveness within real-world contexts.

Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical techniques to examine differences between intervention groups and changes over time. Measures of central tendency and variability were calculated, and appropriate statistical tests were applied to assess the significance of observed differences.

Qualitative data were analyzed using thematic analysis, following a systematic process of coding, categorization, and theme development. This analysis was conducted in accordance with established qualitative research practices, ensuring rigor, transparency, and analytical depth (Braun & Clarke, 2006). Themes were generated inductively, allowing patterns to emerge from participant narratives rather than being imposed a priori. This approach ensured that the findings remained grounded in lived experiences while contributing to theoretical and conceptual development.

Finally, quantitative and qualitative findings were integrated to provide a holistic understanding of sensory regulation, consistent with mixed-methods research principles (Creswell & Plano Clark, 2017).

THEORETICAL FRAMEWORK

The theoretical framework presented in this study offers a multidimensional understanding of sensory regulation in children with Autism Spectrum Disorder (ASD) by integrating the Person–Environment Fit Theory (Law et al., 1996) and Ecological Systems Theory (Bronfenbrenner, 1979). The visual representation highlights that sensory outcomes are not solely determined by intrinsic characteristics of the child but emerge from a dynamic interaction between internal capacities and external environmental conditions. This aligns with contemporary perspectives in autism research, which increasingly reject deficit-only models in favour of relational and interaction-based explanations of development (Dunn, 2007; Schaaf & Mailloux, 2015).

The central concept of dynamic interaction between child and environment illustrates that sensory regulation is contingent upon the degree of alignment, or “fit,” between the child’s sensory processing abilities and the demands of their surroundings. When this alignment is achieved, children are more likely to demonstrate improved behavioral regulation, participation, and learning outcomes. Conversely, a mismatch between internal capacities and environmental stimuli leads to dysregulation, reinforcing the importance of both therapeutic and contextual interventions. This conceptualization reflects the foundational premise of Person–Environment Fit Theory, which posits that optimal functioning is achieved through congruence between individuals and their environments (Law et al., 1996).

Furthermore, the incorporation of Ecological Systems Theory expands this understanding by situating the child within nested systems that influence development, including family, school, community, and broader sociocultural contexts. The framework visually emphasizes that these systems are not isolated but interconnected, meaning that changes in one level (e.g., family stability or school resources) can significantly impact intervention outcomes. This is particularly relevant considering the study’s qualitative findings, which demonstrate how socioeconomic conditions, institutional structures, and cultural attitudes shape the accessibility and effectiveness of interventions. Importantly, the theoretical framework underscores a critical implication: interventions that focus exclusively on the child, without addressing environmental and systemic factors, are inherently limited in their effectiveness. By contrast, approaches that simultaneously target internal regulation (through Occupational Therapy) and external conditions (through Environmental Modifications) are better positioned to achieve sustainable outcomes. Thus, the framework not only explains observed patterns in the data but also provides a theoretical justification for integrative intervention models.

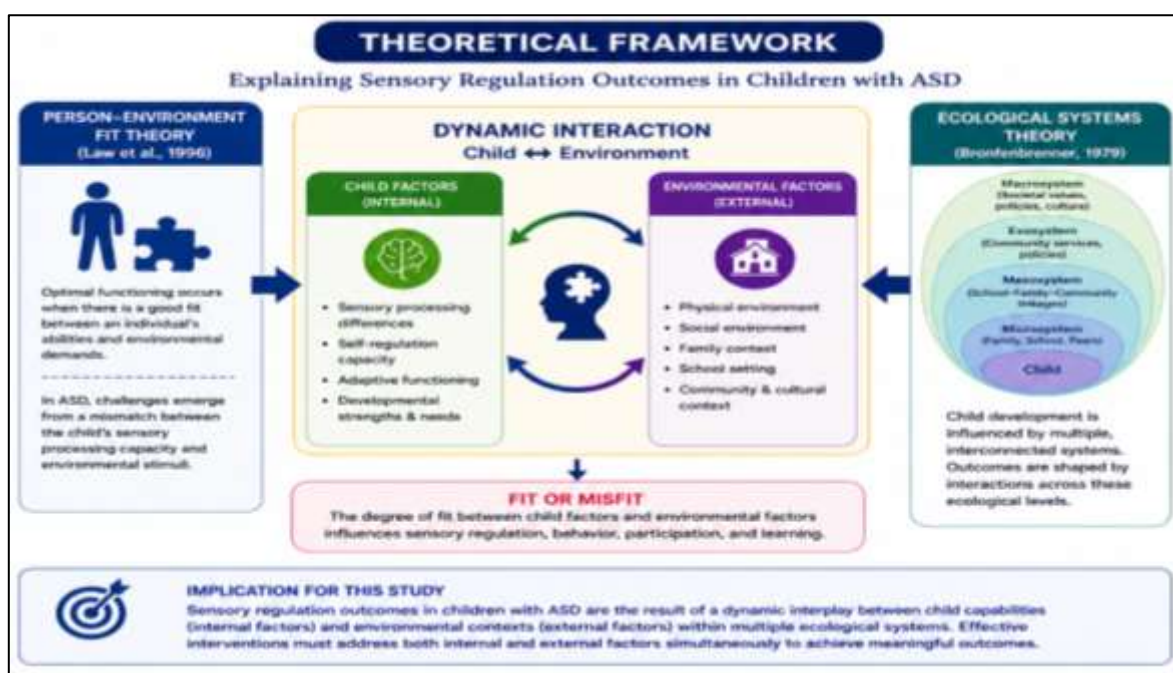


Figure 1. Theoretical Framework Illustrating Sensory Regulation as an Interaction Between Individual Capacities and Environmental Systems in Autism Spectrum Disorder

CONCEPTUAL FRAMEWORK

The conceptual framework translates the theoretical foundations into an applied model that explains how various factors interact to influence sensory regulation outcomes in children with ASD. At its core, the framework presents intervention effectiveness as a multi-layered, process-oriented phenomenon, shaped by the interaction between contextual conditions, intervention mechanisms, and outcome domains. This reflects a shift from linear models of intervention toward more complex, systems-oriented approaches that recognize the interplay between multiple determinants of child development (Ben-Sasson et al., 2009).

The framework begins by positioning contextual and foundational factors, particularly socioeconomic and environmental stability, as the starting point for any effective intervention. This directly corresponds to Theme 1 of the study and highlights that interventions cannot be meaningfully implemented in isolation from the lived realities of families. Financial instability, lack of access to services, and unsafe environments create structural constraints that limit children's ability to benefit from therapeutic support. This finding is consistent with research demonstrating that socioeconomic disadvantage significantly moderates intervention outcomes in developmental disorders (Emerson, 2007).

The second layer of the framework introduces the intervention mechanisms, specifically Occupational Therapy (OT) and Environmental Modifications (EM), conceptualized as internal and external regulation processes, respectively. OT is depicted as enhancing the child's internal capacities, including sensory integration, adaptive functioning, and self-regulation skills, while EM modifies environmental conditions to reduce sensory stressors and facilitate engagement. The bidirectional relationship between these mechanisms emphasizes that they are not independent but mutually reinforcing, supporting a synergistic model of intervention effectiveness (Schaaf et al., 2014).

The framework further incorporates a process-oriented dimension, outlining stages such as assessment, planning, implementation, monitoring, and individualization. This highlights that intervention is not a static event but an ongoing, adaptive process that requires continuous adjustment based on feedback and changing needs. This aligns with best practices in evidence-based intervention, which emphasize the importance of iterative evaluation and contextual responsiveness (Odom et al., 2010).

A particularly important contribution of the framework is the inclusion of Themes 2 and 3, which address the disconnect between perceived efficacy and lived experience and the systemic barriers to implementation. These elements introduce a critical sociological dimension, demonstrating that even well-designed interventions may fail if they are not aligned with family experiences or if systemic constraints hinder their delivery. This reinforces the need for collaborative, family-centered approaches and highlights the role of communication, trust, and institutional capacity in shaping outcomes.

The final component of the framework focuses on outcome domains, including improved sensory regulation, enhanced participation, reduced behavioral challenges, and overall well-being. However, the framework explicitly avoids presenting these outcomes as fixed endpoints. Instead, it introduces a dynamic feedback loop, indicating that outcomes continuously inform and reshape intervention strategies and contextual conditions. This cyclical model reflects the complexity of developmental processes and underscores the importance of flexibility and responsiveness in intervention design.

Overall, the conceptual framework provides a comprehensive and integrative model that captures the complexity of sensory regulation in ASD. By linking individual characteristics, intervention strategies, contextual factors, and systemic influences, it offers both a theoretical contribution and a practical guide for designing more effective, equitable, and sustainable interventions.

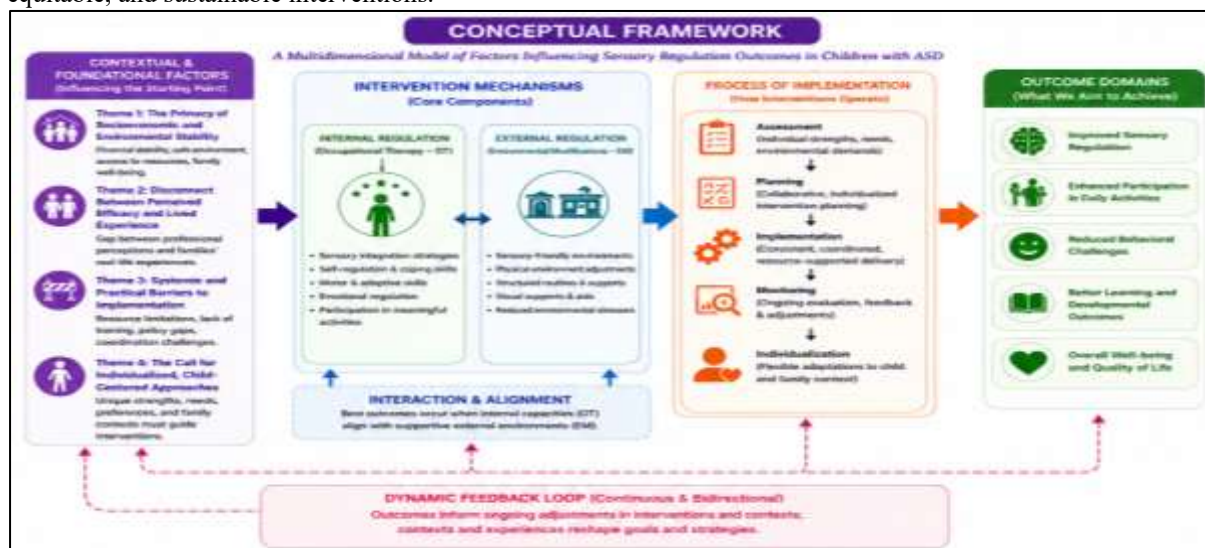


Figure 2. Conceptual Framework of Sensory Regulation in Autism Spectrum Disorder Integrating Occupational Therapy, Environmental Modifications, and Contextual Factors

RESULTS AND FINDINGS

Participant Characteristics

Table 1. Demographic and Contextual Characteristics of Participants

Variable	OT Group (n = 75)	EM Group (n = 75)	Total (N = 150)
Age (Mean ± SD)	7.10 ± 2.30	7.25 ± 2.40	7.18 ± 2.35
Age Range	3–12 years	3–12 years	3–12 years
Gender (Male %)	64%	62%	63%
Gender (Female %)	36%	38%	37%
Educational Setting (School %)	58%	55%	56.5%
Clinical Setting (%)	42%	45%	43.5%
Socioeconomic Status (Low %)	46%	49%	47.5%
Socioeconomic Status (Middle %)	38%	35%	36.5%
Socioeconomic Status (High %)	16%	16%	16%

Note: OT = Occupational Therapy; EM = Environmental Modifications; SES = Socioeconomic Status.

The demographic and contextual characteristics presented in Table 1 indicate that the sample was relatively balanced across intervention groups, enhancing the internal validity of the comparative analysis. The mean age across groups was approximately seven years, with participants spanning a developmental range from early childhood to pre-adolescence, which is particularly relevant given the importance of early and middle childhood in sensory and adaptive development (Dawson et al., 2010).

Gender distribution reflects the well-documented higher prevalence of ASD among males, with approximately two-thirds of the sample being male, consistent with epidemiological patterns reported in the literature (Loomes et al., 2017). Importantly, both intervention groups demonstrate comparable gender proportions, reducing the likelihood of gender-related bias in outcome comparisons.

The distribution across educational and clinical settings suggests that participants were exposed to varied intervention environments, which strengthens the ecological validity of the findings. Additionally, the representation of diverse socioeconomic backgrounds is particularly significant, as socioeconomic status has been shown to influence access to services, consistency of intervention, and developmental outcomes in children with ASD (Emerson, 2007). The relatively high proportion of participants from low and middle socioeconomic groups further underscores the relevance of contextual factors highlighted in the qualitative findings.

Overall, the comparability of groups across demographic and contextual variables supports the robustness of subsequent analyses, ensuring that observed differences in outcomes can be more confidently attributed to intervention effects rather than underlying sample disparities.

Table 2. Comparison of Pre- and Post-Intervention Outcomes Across OT and EM Groups

Outcome Variable	Group	Pre (M ± SD)	Post (M ± SD)	Change (Δ)	p-value	Effect Size (d)
Sensory Regulation	OT	45.20 ± 6.80	62.75 ± 7.10	+17.55	<.001	1.15
	EM	46.10 ± 7.05	57.40 ± 6.90	+11.30	<.01	0.82
Adaptive Functioning	OT	50.30 ± 8.20	66.90 ± 7.50	+16.60	<.001	1.08
	EM	51.00 ± 7.90	60.20 ± 7.30	+9.20	<.05	0.74
Behavioral Challenges	OT	68.40 ± 9.10	52.10 ± 8.40	-16.30	<.001	1.02
	EM	67.90 ± 8.70	55.80 ± 8.10	-12.10	<.01	0.88
Participation Level	OT	42.75 ± 6.50	59.60 ± 6.80	+16.85	<.001	1.12
	EM	43.20 ± 6.70	54.10 ± 6.60	+10.90	<.01	0.79

Note: Higher scores indicate improvement for all variables except Behavioral Challenges, where lower scores indicate improvement.

The findings presented in Table 2 indicate that both Occupational Therapy (OT) and Environmental Modifications (EM) contributed to statistically significant improvements across all measured domains; however, the magnitude and nature of these improvements differed systematically between groups. Children in the OT group demonstrated

larger gains in sensory regulation, adaptive functioning, and participation, with effect sizes exceeding 1.0 in several domains, suggesting strong and clinically meaningful improvements. This pattern reflects the capacity of OT to enhance internal sensory processing mechanisms and promote skill acquisition over time (Schaaf et al., 2014).

In contrast, the EM group also exhibited significant improvements, particularly in reducing behavioral challenges and enhancing participation, although effect sizes were comparatively moderate. These findings suggest that while EM is effective in stabilizing behavior through contextual adjustments, its impact on long-term developmental capacities may be more limited when implemented independently. Importantly, both groups showed reductions in behavioral challenges, reinforcing the role of both internal and external regulatory mechanisms in managing dysregulation.

Overall, the results support a differentiated yet complementary understanding of intervention effects, where OT primarily facilitates internal developmental change, and EM provides immediate environmental support. This distinction aligns with interaction-based models of intervention, emphasizing that optimal outcomes are achieved through the alignment of internal capacities and external conditions (Law et al., 1996).

Qualitative Findings

Table 3. Summary of Qualitative Themes and Analytical Interpretations

Theme	Core Meaning	Analytical Insight	Illustrative Evidence
Theme 1: Socioeconomic & Environmental Stability	Stability shapes intervention success	Context acts as a foundational determinant	“Without basic stability, therapy cannot show real results”
Theme 2: Perceived vs Lived Efficacy	Gap between theory and reality	Contextual mismatch limits effectiveness	“It works in therapy, but not at home”
Theme 3: Systemic Barriers	Institutional constraints hinder delivery	Structural limitations reduce consistency	“We lack trained staff and proper resources”
Theme 4: Individualized Approaches	Need for personalization	Standardized models fail diverse needs	“Each child requires a unique plan”

The qualitative findings summarized in Table 3 provide critical insight into the contextual and systemic dimensions that shape intervention effectiveness. Theme 1 highlights the centrality of socioeconomic and environmental stability, suggesting that interventions operate within broader structural conditions that either enable or constrain their success. This reinforces ecological perspectives of development, which emphasize the influence of contextual factors on child outcomes (Bronfenbrenner, 1979).

Theme 2 reveals a notable disconnect between professional perceptions of intervention efficacy and the lived experiences of families. While interventions may demonstrate success in controlled settings, their translation into everyday contexts is often inconsistent, reflecting a gap between theory and practice. This finding underscores the importance of aligning intervention design with real-world conditions and family needs.

Theme 3 further identifies systemic and institutional barriers, including resource limitations, inadequate training, and weak coordination, which disrupt the delivery and sustainability of interventions. These barriers highlight the need for structural reforms to support effective implementation. Finally, Theme 4 emphasizes the necessity of individualized, child-centered approaches, recognizing the heterogeneity of ASD and the limitations of standardized models.

Together, these themes illustrate that intervention outcomes are not determined solely by therapeutic inputs but are shaped by a complex interplay of individual, contextual, and systemic factors. This multidimensional understanding aligns with contemporary qualitative research approaches, where themes emerge inductively from participant experiences and reflect deeper patterns within the data (Braun & Clarke, 2006).

Integration of Qualitative Findings with Conceptual Framework

Table 4. Alignment of Qualitative Themes with Conceptual Framework Components

Theme	Framework Component	Role in Intervention	Implication
Socioeconomic & Environmental Stability	Contextual Foundation	Enables or constrains outcomes	Stability is prerequisite for effectiveness
Perceived vs Lived Efficacy	Relational Process	Mediates implementation	Align interventions with family experiences
Systemic Barriers	Systemic Structure	Limits delivery	Strengthen institutional support

Theme	Framework Component	Role in Intervention	Implication
Individualized Approaches	Intervention Design	Drives outcomes	Personalization is essential

The integration presented in Table 4 demonstrates how qualitative themes correspond to distinct components of the conceptual framework, providing a cohesive understanding of intervention effectiveness. The alignment indicates that sensory regulation outcomes are shaped through the interaction of contextual, relational, systemic, and individual factors rather than through isolated intervention mechanisms.

This integrative perspective reinforces the study’s central argument that effective intervention in ASD requires a multidimensional approach. Contextual stability establishes the foundation for intervention, relational alignment ensures real-world applicability, systemic structures determine feasibility, and individualized design enhances responsiveness to diverse sensory profiles. Together, these elements form a dynamic system in which outcomes continuously evolve through interaction and feedback.

Comparative Outcome Summary

The comparative analysis of intervention outcomes reveals distinct yet complementary patterns in the effectiveness of Occupational Therapy (OT) and Environmental Modifications (EM). Children receiving OT demonstrated significant improvements in sensory integration, adaptive functioning, and engagement in structured activities. These findings indicate that OT plays a critical role in strengthening internal sensory regulation mechanisms and facilitating long-term developmental progress. In contrast, participants exposed to Environmental Modifications exhibited reductions in sensory overload, improved behavioral stability, and increased participation in daily environments. These outcomes highlight the importance of contextual adjustments in managing sensory challenges, particularly in reducing immediate environmental stressors and supporting functional engagement.

A comparative examination of both intervention approaches indicates that OT primarily contributes to the development of internal regulatory capacities, whereas EM enhances external environmental conditions that support behavioral stability. Notably, the combined application of these approaches appears to produce the most substantial and sustained improvements, suggesting that optimal outcomes are achieved through the integration of internal skill development and environmental regulation.

6.4 Qualitative Analysis: Interpreting Sensory Regulation through Therapeutic and Environmental Lenses

The qualitative component of this study was analyzed using a thematic approach informed by Braun and Clarke (2006), enabling both descriptive richness and interpretative depth in understanding sensory regulation in children with Autism Spectrum Disorder (ASD). Unlike purely quantitative evaluations of intervention outcomes, this approach facilitated the exploration of how Occupational Therapy (OT) and Environmental Modifications (EM) are experienced, interpreted, and implemented within real-world contexts. The analysis followed an inductive process, allowing patterns to emerge from the narratives of caregivers and therapists who directly engage with children in both clinical and everyday settings.

The findings indicate that sensory regulation cannot be adequately understood as an isolated clinical phenomenon. Instead, it is embedded within a broader relational and environmental context, supporting contemporary perspectives that emphasize interaction-based models over deficit-oriented explanations (Ben-Sasson et al., 2009; Schaaf & Mailloux, 2015). The themes derived from the data therefore extend existing knowledge by capturing the lived realities and contextual complexities that shape intervention effectiveness.

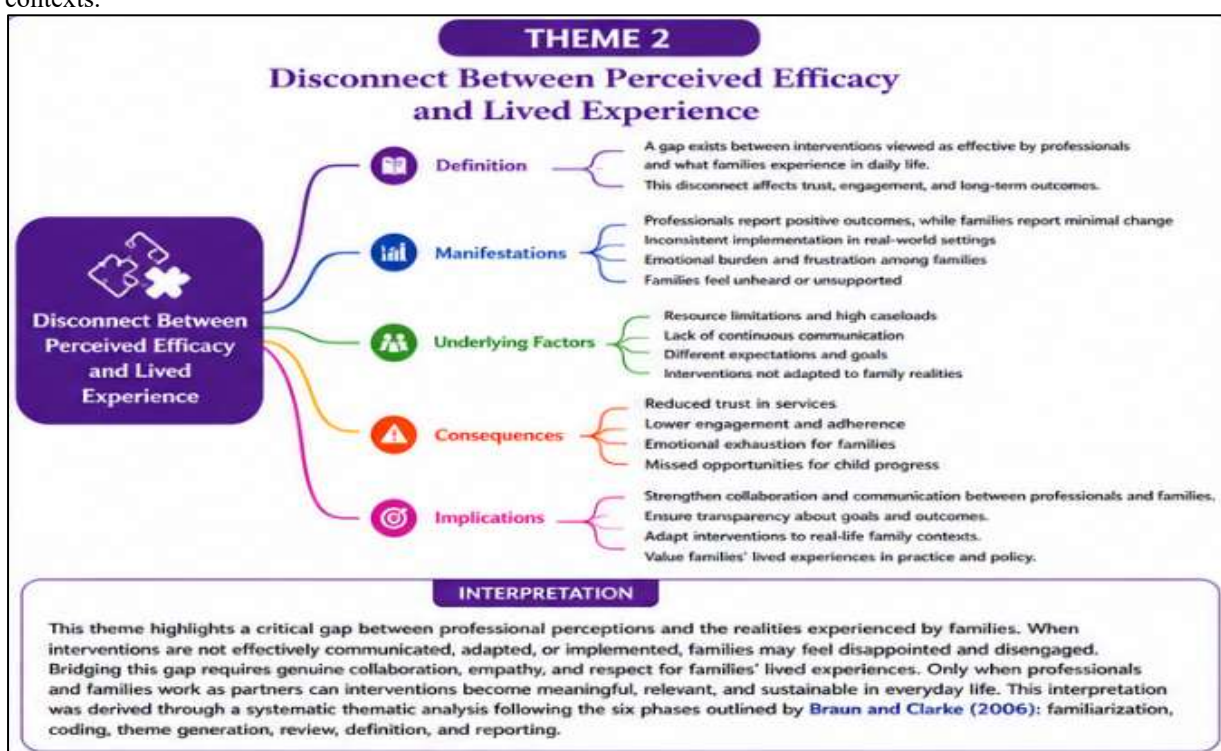
Theme 1: The Primacy of Socioeconomic & Environmental Stability

One of the most dominant themes emerging from the data was the reconceptualization of sensory dysregulation as a phenomenon that cannot be fully explained by intrinsic neurological deficits alone. Participants repeatedly emphasized that children’s sensory responses varied significantly depending on environmental conditions, suggesting that behavior is co-constructed through interaction with contextual stimuli. Caregivers described how the same child who exhibited extreme distress in noisy or visually overwhelming environments could function relatively calmly in structured and predictable settings. This observation challenges traditional clinical assumptions that locate sensory difficulties exclusively within the child. Instead, it supports an ecological perspective in which environmental demands play an equally significant role in shaping behavioral outcomes (Dunn, 2007). This theme is particularly important in advancing theoretical understanding because it reframes sensory challenges as relational rather than static. The implication is that interventions should not focus solely on “fixing” the child but must also address environmental mismatches. This insight provides a conceptual bridge between Occupational Therapy and Environmental Modifications, positioning them not as competing approaches but as addressing different dimensions of the same phenomenon.



Theme 2: Disconnect Between Perceived Efficacy and Lived Experience

The analysis further highlights Occupational Therapy as a key mechanism for strengthening internal sensory regulation capacities. Both therapists and caregivers described OT as a structured and gradual process through which children develop improved tolerance to sensory stimuli, enhanced engagement in tasks, and greater adaptive functioning. Therapists described OT sessions as “gradual exposure systems,” in which children are supported to interact with sensory inputs in controlled and meaningful ways. Over time, this process facilitates neural adaptation and behavioral flexibility, enabling children to function more independently across settings. This finding is consistent with existing literature demonstrating the effectiveness of sensory integration interventions in improving functional outcomes (Schaaf et al., 2014). However, the analysis also revealed a critical nuance: the effectiveness of OT is not immediate. Caregivers often reported that progress was incremental and required sustained effort over extended periods. This temporal dimension highlights a key limitation of OT when used in isolation, particularly in environments that continue to present overwhelming sensory demands. Without supportive environmental conditions, the gains achieved through therapy may not fully generalize to everyday contexts.

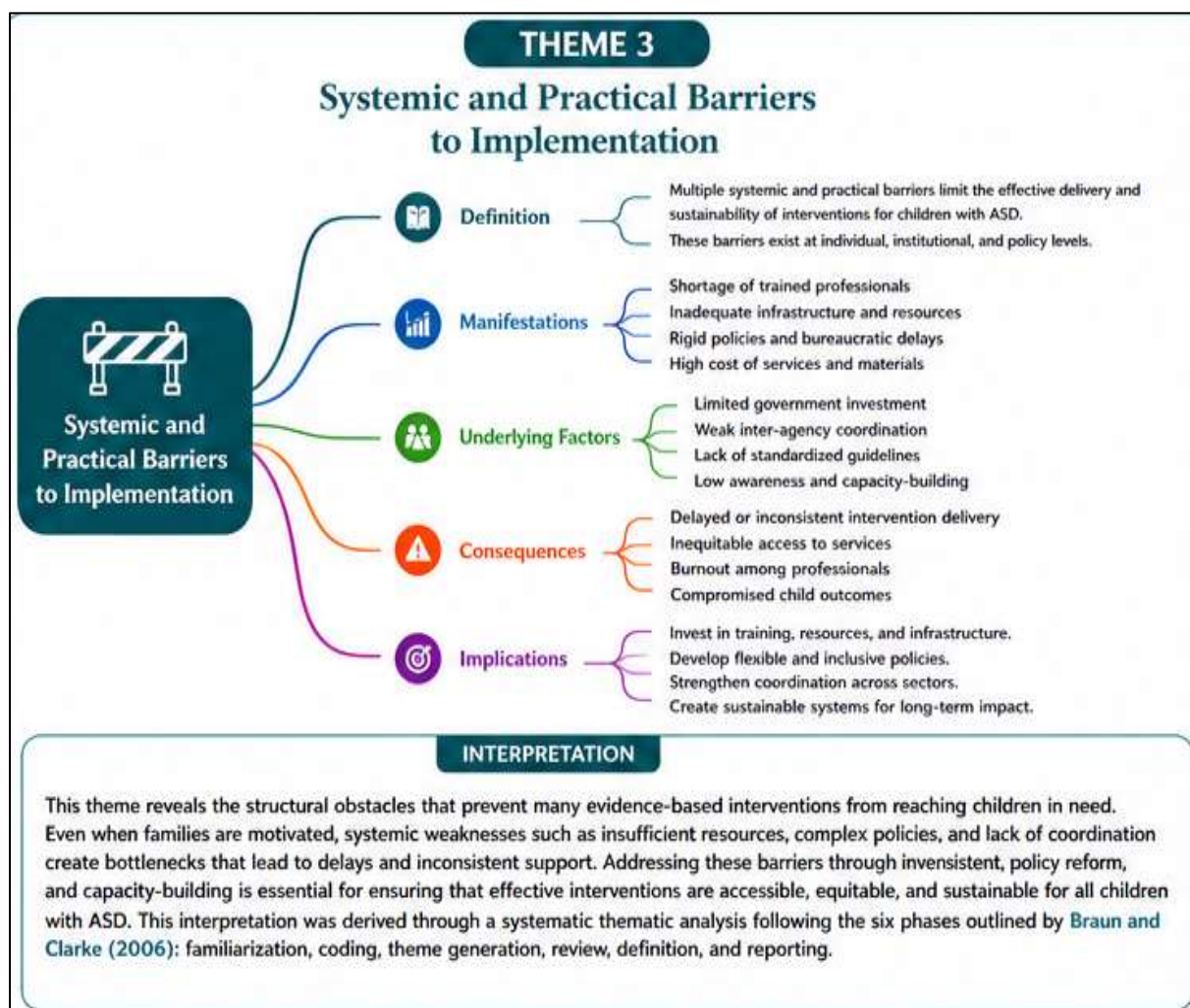


Theme 3: Systematic and Practical Barriers to Implementation

In contrast to Occupational Therapy, Environmental Modifications were consistently described as producing immediate and observable improvements in children’s behavior. Participants reported that adjustments such as reducing noise levels, structuring physical spaces, and introducing visual supports significantly decreased sensory overload and behavioral dysregulation.

Caregivers frequently conceptualized EM as a form of “protective buffering”, creating environments that minimize sensory stressors and facilitate engagement. This interpretation aligns with research demonstrating that structured and predictable environments can reduce anxiety and improve attention in children with ASD (Ashburner et al., 2008).

Despite these benefits, participants also recognized the limitations of EM. While environmental adjustments effectively stabilize behavior, they do not directly enhance internal sensory processing capacities. Instead, EM operates by modifying external conditions, suggesting that its impact may be context-dependent and potentially less sustainable in the absence of ongoing environmental support.

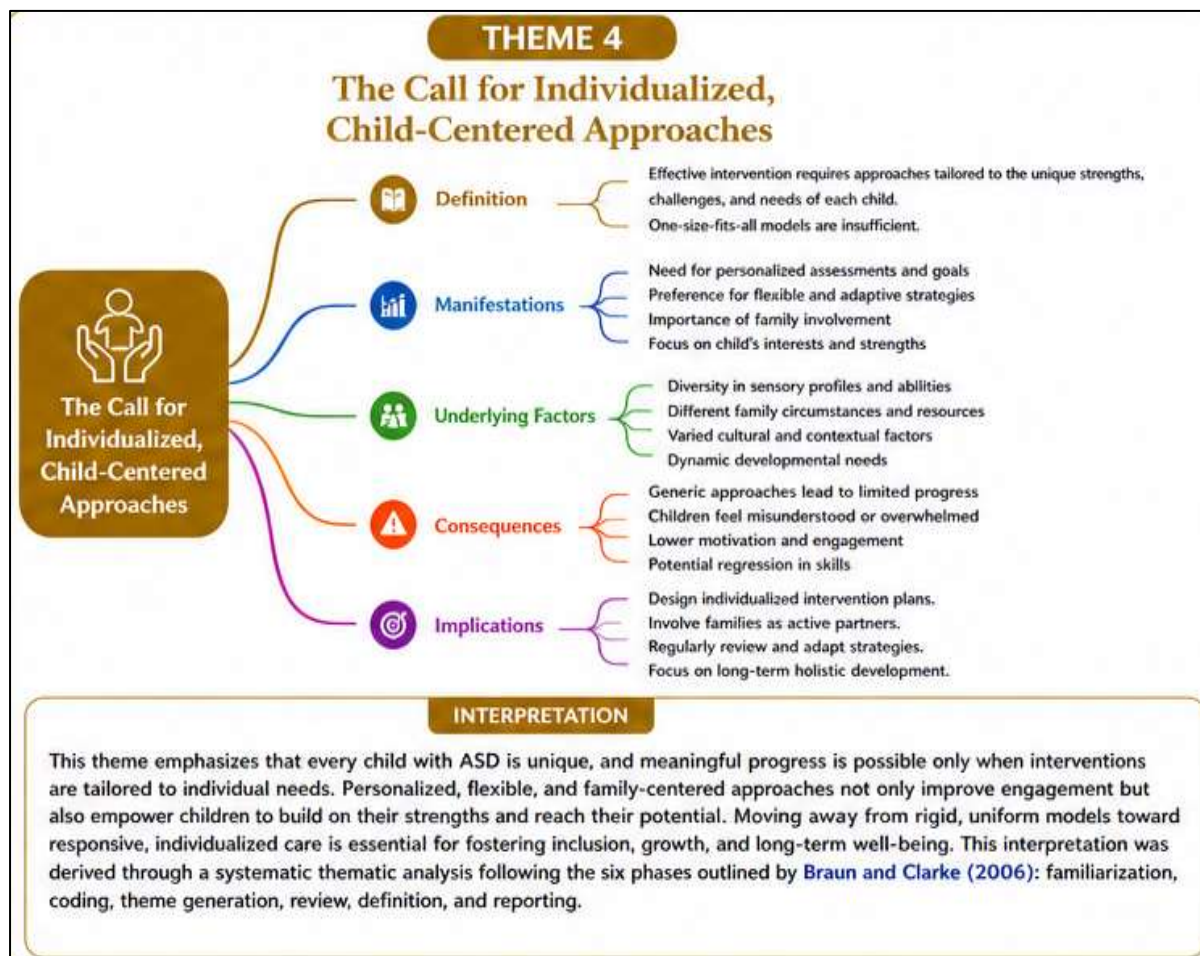


Theme 4: The Call for Individualized, Child Centered Approaches

A key insight emerging from the analysis is the recognition that neither OT nor EM alone is sufficient to fully address sensory challenges in ASD. Participants consistently emphasized the importance of integrating both approaches to achieve more comprehensive and sustainable outcomes.

Therapists reported that children receiving combined interventions demonstrated more consistent improvements across settings, highlighting the importance of aligning internal capacities with environmental demands. This finding strongly supports the person–environment interaction framework, which posits that optimal functioning occurs when there is congruence between individual abilities and environmental conditions (Law et al., 1996).

The integrative model proposed in this study therefore represents a significant advancement in intervention research. By moving beyond the dichotomy of therapy versus environment, it conceptualizes sensory regulation as an emergent property of their interaction. This perspective not only enhances theoretical understanding but also provides practical guidance for designing more effective and context-sensitive intervention strategies.



Analytical Synthesis

Taken together, the qualitative findings provide a nuanced understanding of how and why interventions influence sensory regulation in ASD. While Occupational Therapy facilitates long-term developmental change through the enhancement of internal regulatory mechanisms, Environmental Modifications offer immediate contextual support that enables children to function more effectively in their environments.

This duality reinforces a central conclusion of the study: sensory challenges in ASD are neither purely internal nor purely external but are dynamically produced through continuous interaction between the child and their environment. Consequently, intervention strategies must reflect this complexity by integrating multiple approaches rather than relying on isolated solutions.

DISCUSSION

The present study provides a comprehensive and integrative examination of sensory regulation interventions in children with Autism Spectrum Disorder (ASD), demonstrating that sensory challenges cannot be adequately understood or addressed through single-modality approaches. By combining quantitative outcomes with qualitative insights, the findings advance a multidimensional perspective in which sensory regulation emerges through dynamic interactions between internal capacities, environmental conditions, and systemic structures.

A central contribution of this study lies in its empirical support for the Person–Environment Fit perspective, which posits that optimal developmental outcomes occur when there is alignment between individual abilities and environmental demands (Law et al., 1996). The quantitative findings indicate that Occupational Therapy (OT) produces stronger improvements in internal sensory integration, adaptive functioning, and participation, whereas Environmental Modifications (EM) contribute to immediate reductions in behavioral dysregulation through contextual stabilization. This distinction reinforces the complementary nature of these interventions and highlights that neither approach alone is sufficient to address the complexity of sensory challenges in ASD (Schaaf et al., 2014; Ashburner et al., 2008).

The qualitative findings further extend this understanding by emphasizing the critical role of contextual and environmental conditions in shaping intervention effectiveness. The prominence of socioeconomic and environmental stability underscores that interventions are embedded within broader structural realities that either enable or constrain their success. This aligns with ecological perspectives of development, which emphasize the influence of multiple interacting systems on child outcomes (Bronfenbrenner, 1979). Moreover, research in

educational contexts has consistently demonstrated that physical facilities, institutional resources, and environmental quality significantly influence children's developmental and behavioral outcomes (Ullah et al., 2024a; Ullah et al., 2024b; Ullah et al., 2025). These findings strengthen the argument that environmental factors are not peripheral but foundational to intervention success.

Another key insight is the identified disconnect between perceived efficacy and lived experience. While interventions may demonstrate effectiveness in structured clinical environments, their translation into everyday contexts is often inconsistent. This gap reflects broader challenges in implementation science, where evidence-based practices fail to achieve expected outcomes due to contextual variability and systemic limitations (Odom et al., 2010). The findings highlight the necessity of aligning therapeutic practices with real-world conditions and family experiences, ensuring that interventions are both contextually relevant and practically sustainable.

The study also highlights systemic barriers, including limited access to trained professionals, inadequate institutional support, and resource constraints, which significantly hinder the implementation and scalability of interventions. These challenges are particularly pronounced in resource-constrained settings, where disparities in infrastructure and policy implementation affect service delivery. Empirical evidence from educational and policy research further supports this observation, indicating that deficiencies in physical facilities, inclusive education practices, and institutional management directly impact developmental outcomes (Ullah et al., 2024c; Ullah et al., 2026a; Ullah & Ghazi, 2026). These findings emphasize that effective intervention requires not only clinical expertise but also systemic capacity and policy support.

Finally, the strong emphasis on individualized, child-centered approaches reflects the heterogeneity of ASD and reinforces the limitations of standardized intervention models. Tailoring interventions to the unique sensory profiles, developmental trajectories, and contextual conditions of each child is essential for achieving meaningful and sustainable outcomes. This perspective is consistent with established best practices in autism intervention research, which advocate for flexible, adaptive, and personalized approaches (Dawson et al., 2010; National Research Council, 2001).

Overall, the findings support a paradigm shift from deficit-based models toward interaction-based frameworks of sensory regulation. By integrating internal and external dimensions of intervention and situating them within broader contextual and systemic conditions, this study contributes to a more comprehensive and theoretically grounded understanding of intervention effectiveness in ASD.

IMPLICATIONS

The findings of this study carry significant implications across clinical practice, theory, and policy domains. From a clinical perspective, the results strongly support the integration of Occupational Therapy and Environmental Modifications within a unified intervention framework. Practitioners should move beyond isolated treatment models and adopt holistic approaches that simultaneously address internal sensory capacities and external environmental conditions.

From a theoretical standpoint, this study contributes to a shift from deficit-oriented models toward interaction-based frameworks that conceptualize sensory regulation as a relational process. By integrating person-environment and ecological perspectives, it advances a more nuanced understanding of developmental functioning in ASD.

From a policy perspective, the identification of systemic barriers highlights the urgent need for investment in infrastructure, professional training, and resource allocation. Evidence from educational research further suggests that improvements in physical facilities, inclusive practices, and institutional management can significantly enhance developmental outcomes (Ullah et al., 2024d; Shafqatullah et al., 2026). Policymakers must therefore prioritize coordinated, interdisciplinary systems that support both therapeutic and environmental interventions.

LIMITATIONS

Despite its contributions, this study is subject to several limitations. First, the sample, while diverse, may not fully represent all subgroups of children with ASD, particularly those with severe comorbid conditions or those from highly marginalized contexts, thereby limiting generalizability. Second, the reliance on caregiver and professional reports introduces the potential for subjective bias, although efforts were made to triangulate data sources. Third, the study's timeframe may not capture the long-term sustainability of intervention outcomes, as sensory and developmental changes often occur over extended periods.

FUTURE RESEARCH DIRECTIONS

Future research should focus on longitudinal studies that examine the sustained interaction between internal and environmental factors in shaping developmental outcomes. There is also a need for context-specific research that explores how cultural, socioeconomic, and institutional differences influence intervention effectiveness. Emerging areas such as technology-assisted interventions, hybrid models, and community-based approaches offer promising directions for further investigation.

CONCLUSION

This study demonstrates that sensory regulation in children with Autism Spectrum Disorder is a complex and dynamic process that cannot be effectively addressed through isolated intervention strategies. By integrating quantitative and qualitative findings, the study highlights the importance of aligning internal capacities with external environmental conditions within a broader systemic context.

The findings underscore the complementary roles of Occupational Therapy and Environmental Modifications while emphasizing the critical influence of socioeconomic stability, systemic structures, and individualized approaches. Ultimately, the study calls for a shift toward integrated, context-aware, and child-centered intervention models that reflect the multidimensional nature of developmental challenges in ASD.

RECOMMENDATIONS

The study recommends that clinicians adopt integrated intervention strategies that combine therapeutic skill development with environmental adaptation. Educational institutions and therapy centers should implement structured systems that support individualized planning and interdisciplinary collaboration.

At the policy level, there is a need for increased investment in infrastructure, training, and resources to address systemic barriers and ensure equitable access to services. Policymakers should also prioritize the development of coordinated frameworks that integrate health, education, and social services.

Finally, researchers should continue to explore innovative, context-sensitive approaches that bridge the gap between clinical efficacy and real-world applicability, ensuring that future intervention models are both evidence-based and practically sustainable.

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