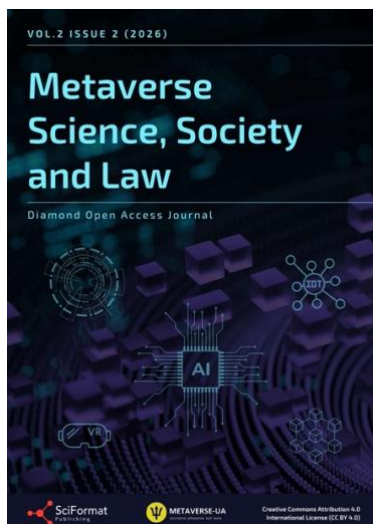




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UNOWA SIX DEVELOPMENTAL DOMAINS PILOT STUDY: SENSORY FUNCTIONING AS A DISTINCT REGULATORY CONSTRUCT IN MULTIDIMENSIONAL DEVELOPMENTAL ASSESSMENT

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ABSTRACT

Sensory functioning is often included in developmental assessment as an auxiliary domain, although sensory regulation may directly shape attention, behavior, communication, participation, and adaptive functioning. This article examines sensory functioning as a distinct regulatory construct within a multidimensional developmental assessment model. The analysis is based on the UNOWA Six Developmental Domains pilot study, Version 2.0, conducted with 153 children aged 18–83 months. The instrument assessed five functional domains: cognitive, social, physical, sensory, and daily living skills. Each domain was scored using a Percentage Score from 0 to 100%, calculated from applicable age-based items. The sensory domain used an inverted scoring logic, where higher scores reflected greater sensory well-being.

The pilot data showed that sensory functioning behaved differently from the other developmental domains. Although the sensory domain showed a statistically significant but weak association with age, its correlation with age was substantially lower than that of the social, daily living, physical, and cognitive domains. In the interdomain correlation matrix, sensory functioning showed weak or near-zero associations with the other domains. Exploratory factor analysis further supported its distinct status: in the one-factor solution, the sensory domain had almost no loading on the general developmental factor, while in the two-factor solution it loaded strongly on a separate factor. Item analysis also indicated that the sensory domain requires refinement, with ceiling/floor effects and low item discrimination observed across the item pool.

These findings support the interpretation of sensory functioning not as a simple age-linear developmental scale, but as a regulatory profile that describes the conditions under which a child can remain organized, participate, learn, and adapt. The article argues for further differentiation of the sensory domain into subcomponents such as sensory hyperresponsivity, hyporesponsivity, sensory seeking, sensory avoidance, switching, activation, passivity, and self-regulation. The findings have implications for inclusive education, early intervention, individualized support planning, and future AI-assisted interpretation within the HumanAI UNOWA framework.

KEYWORDS

Sensory Functioning, Sensory Regulation, Developmental Assessment, Inclusive Education, Psychometrics, UNOWA, Humanai UNOWA

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Introduction

Developmental assessment traditionally focuses on domains that are expected to show gradual age-related progression: cognitive development, social interaction, motor functioning, adaptive behavior, communication, and daily living skills. These domains are usually interpreted through a developmental logic: as children grow older, they are expected to follow more complex instructions, demonstrate more advanced problem-solving, show increasing social participation, improve motor coordination, and acquire greater independence in everyday routines. Such developmental domains are typically expected to correlate positively with chronological age.

Sensory functioning, however, does not necessarily follow the same age-linear pattern. Sensory functioning refers to the way a child receives, filters, integrates, tolerates, and responds to information from sensory channels, including auditory, tactile, visual, vestibular, proprioceptive, olfactory, and oral sensory input. It is closely connected to behavioral organization, emotional regulation, attention, participation, and the child's ability to remain available for learning. For this reason, sensory functioning may be better understood not simply as a developmental skill, but as a regulatory condition under which other skills can be expressed.

Reflecting this conceptual paradigm, sensory functioning is increasingly recognized as a core regulatory construct in child development and autism spectrum disorders (ASD), rather than a minor auxiliary domain. Contemporary empirical work emphasizes its foundational links to social communication, adaptive behavior, mental health trajectories, and individualized intervention planning (Consoli et al., 2025; Kalitkin, 2026).

Conceptualization of Sensory Functioning and Phenotypes

The UNOWA pilot framework specifically positions sensory functioning as a distinct, weakly age-related regulatory profile that remains largely separable from cognitive, social, motor, and daily living domains within factor-analytic models (Kalitkin, 2026). To capture the nuance of this profile, the framework proposes a series of specialized subcomponents, including sensory hyperresponsivity, hyporesponsivity, seeking, avoidance, environmental switching, activation, passivity, and broader self-regulation (Kalitkin, 2026).

The theoretical foundation for this multidimensional view can be traced back to classical sensory integration theory, which highlighted the critical role of sensory processing in learning, motor planning, and adaptive behavior (Ayres, 1972). Subsequent sensory processing frameworks further elaborated on these individual differences, categorizing distinct neurological thresholds and behavioral response patterns, such as sensory seeking, sensory avoiding, sensory sensitivity, and low registration (Dunn, 1997, 2014). These typologies are highly relevant when working with children exhibiting neurodevelopmental profiles—including autism, general developmental delays, language impairments, and attentional difficulties—where atypical sensory features directly influence daily functioning (Baranek et al., 2006; Ben-Sasson et al., 2009; Miller et al., 2007).

Recent data-driven investigations involving large clinical cohorts have sought to map these individual differences onto distinct sensory phenotypes and subtypes. For instance, K-means clustering analysis of 599 autistic individuals successfully delineated five specific sensory phenotypes (e.g., generalized processing differences, isolated taste/smell sensitivity, and a combined under-responsive/seeking profile), each demonstrating unique associations with adaptive behaviors and co-occurring clinical traits (Scheerer et al., 2021). Similarly, evaluations within mixed neurodevelopmental cohorts have revealed five latent sensory subtypes—ranging from Typical and Intermediate/Mixed to Over-Responsive, Seeking, and Under-Responsive profiles—with each subtype uniquely predicting specific patterns of childhood anxiety, ADHD symptoms, and systemic emotion dysregulation (Brandes-Aitken et al., 2024).

The clinical and functional relevance of these subscales is further underscored by population-level surveillance data, which indicate that atypical sensory features are present in up to 74% of large autistic cohorts ($N > 25,000$), presenting strong correlations with impairments in adaptive behavior, emotional volatility, aggression, attention deficits, localized fears, motor execution, eating habits, and sleep architecture (Kirby et al., 2022). Comprehensive state-of-the-art reviews confirm that atypical sensory responsivity manifests early in development, is deeply rooted in neurobiological mechanisms, and is structurally intertwined with these co-occurring behavioral and physical challenges (Consoli et al., 2025).

Neurobiological and Regulatory Mechanisms

From a mechanistic perspective, functional neuroimaging paradigms in autistic youth have successfully linked behavioral manifestations like sensory over-responsivity (SOR) to clear neural markers, specifically impaired habituation and altered functional connectivity within the amygdala–prefrontal circuitry (Green et al., 2019). High-SOR individuals exhibit a markedly reduced capacity to maintain neural habituation inside the amygdala and primary sensory cortices when exposed to sensory stimuli, alongside an inability to sustain the top-down inhibition of irrelevant cortical regions over time (Green et al., 2019). Conversely, low-SOR autistic youth exhibit distinct neural irregularities characterized by reduced responsiveness to novel stimuli alongside heightened prefrontal–amygdala regulatory activation; this pattern strongly suggests that top-down neurobiological regulatory mechanisms dictate whether underlying atypical brain responses ultimately manifest as observable behaviors (Green et al., 2019).

The expanding research base surrounding these mechanisms is evident in recent scientometric and narrative syntheses of Sensory Integration Theory and the Sensory Processing Measure (SPM), which demonstrate an exponential growth in literature after 2011, heavily clustering around sensory behaviors, classroom contextual factors, electroencephalography (EEG) biomarkers, and the comparative effectiveness of targeted therapies (Alotaibi et al., 2025).

This literature underscores the pervasive impact of Sensory Processing Disorder (SPD), conceptualized as altered sensory integration that disrupts behavioral and motor planning, subsequently hindering learning, coordination, and language development; current estimates place SPD prevalence between 5% and 15% in Western child populations, noting significant secondary risks for chronic stress, anxiety, and depression (Galiana-Simal et al., 2020). Direct behavioral comparisons between preschool children with ASD and those with isolated SPD demonstrate that while both groups exhibit severe sensory-driven behavioral challenges, children with ASD generally experience broader impairments where sensory dysfunction cascades into motor difficulties, whereas isolated SPD exhibits a highly localized relationship between disrupted body awareness and rigid, ritualistic behaviors (Purpura et al., 2022).

In educational and clinical practice, these underlying sensory-regulatory difficulties are frequently misinterpreted as volitional behavioral opposition or disciplinary infractions. For example, a child who covers their ears is often viewed as refusing instructional authority, when the action is actually a regulatory attempt to mitigate acute auditory overload. Similarly, a child who repeatedly leaves their seat may be labeled as inattentive or defiant, whereas the behavior may stem from an intrinsic regulatory requirement for proprioceptive or vestibular stabilization. Furthermore, avoidance behaviors targeting specific textures, art mediums, foods, or group environments are rarely driven by a lack of intrinsic motivation, but are rather indicators of sensory intolerance and avoidance strategies. Implementing objective sensory assessments can effectively pivot the educational focus from discipline to proactive environmental adaptation.

The UNOWA Six Developmental Domains assessment framework offers an empirically grounded mechanism to evaluate these sensory profiles alongside traditional developmental milestones. While the complete conceptual architecture of the UNOWA framework encompasses six unique spheres of functioning, the current pilot psychometric investigation isolates five primary domains: cognitive, social, physical, sensory, and daily living skills.

Crucially, the sensory domain utilizes an inverted scoring system, meaning that an elevated score signifies superior sensory well-being and fewer processing disruptions. This structural choice differentiates the sensory scale from traditional developmental metrics where "more skills equal a higher score." Instead, it is designed to capture the exact extent to which a child's sensory-regulatory system supports or destabilizes their broader behavioral execution.

The primary objective of this article is to demonstrate that sensory functioning operates as an independent regulatory construct that should not be collapsed into general developmental matrices. Utilizing the UNOWA pilot data, we demonstrate that the sensory domain exhibits an entirely distinct psychometric profile compared to cognitive, social, physical, and adaptive domains, characterized by a minimal association with chronological age, isolated interdomain correlations, a unique factor structure, and pronounced internal heterogeneity across items. Collectively, these findings validate the transition toward a more differentiated, subscale-driven sensory architecture in subsequent iterations of the tool.

Assessment: Multidomain Developmental Tools and Psychometrics

Multidomain Developmental Measures (0–3 years)

By embedding an inverted sensory domain directly alongside cognitive, social, physical, and daily living metrics, the UNOWA Six Domains pilot demonstrates that sensory scores remain independent of age-linear skill progression and exhibit virtually no loading on general developmental factors, confirming its status as an isolated regulatory variable (Kalitkin, 2026).

This approach stands in contrast to several other major global multi-domain initiatives. For example, the Global Scales for Early Development (GSED) project engineered its Short Form (caregiver-report) and Long Form (direct assessment) for children aged 0–3 through an extensive Rasch-based selection process, filtering an initial databank of 66,075 children down to 139 and 157 highly optimized items based on expert consensus regarding cross-cultural feasibility and domain equilibrium (McCray et al., 2023). While the GSED instruments deliver highly stable, cross-culturally invariant assessments across primary functional areas, their public models do not explicitly isolate an independent sensory processing construct.

A similar structural paradigm is observed in the Caregiver Reported Early Development Instruments (CREDI) long form, which leverages multidimensional item factor analysis to generate population-level subscales for motor, cognitive, language, and socio-emotional milestones in children under age three (Waldman et al., 2021). Although the CREDI subscales demonstrate robust internal consistency, test-retest reliability, and strong criterion-related validity against anthropometric and established clinical tools, sensory processing is not partitioned as an independent subscale.

The historical absence or fragmentation of sensory and regulatory metrics within global instruments is widely recognized. A systematic review examining 117 early childhood development tools deployed across 160 articles in low- and middle-income countries (LMICs) revealed that while psychometric evaluations frequently targeted internal consistency (64%), concurrent validity (45%), and convergent validity (41%), rigorous testing for measurement invariance remained critically scarce (9%) (Bliznashka et al., 2025). Furthermore, the available data were heavily urban-biased and concentrated almost exclusively on language, motor, and cognitive milestones, emphasizing a clear gap in globally validated metrics designed to capture sensory-regulatory variance.

This assessment landscape is further complicated by shifting delivery modalities. A recent realist review of digitally delivered developmental screening tools for children aged 0–5 established that digital adaptations of major instruments—including the ASQ-2, R-PDQ, Vineland, Bayley-3, and select NEPSY-II subtests—can achieve strong within- or between-group psychometric equivalence compared to traditional paper-and-pencil administrations, with the digital Bayley-3 demonstrating high inter-observer reliability (0.82–1.0) (Komanchuk et al., 2023). However, the successful execution of these digital platforms remains highly dependent on active examiner guidance, baseline technological modifications, and family socioeconomic resources, and these tools continue to evaluate broader functional areas without isolating sensory processing as a distinct regulatory moderator.

Sensory-Specific Assessment Frameworks

To address these measurement gaps, specialized sensory assessment frameworks have evolved independently. Prominent among these is the Sensory Processing Measure (SPM), which is anchored in classical Sensory Integration Theory and spans a developmental range from 4 months to 87 years; scientometric evaluations of over 238 comprehensive records demonstrate its widespread utility across educational settings, clinical trials, and EEG-based biomarker research, highlighting its capacity to differentiate sensory phenotypes in ASD from neurotypical trajectories and map relationships with broader functional domains (Alotaibi et al., 2025).

Methodological reviews of sensory assessment in ASD highlight the necessity of capturing distinct phenotypic expressions—specifically isolating hyperresponsiveness, hyporesponsiveness, and specialized sensory seeking behaviors—to accurately inform diagnostic classifications and therapeutic design (Baranek et al., 2014). This critical need for multidimensional, targeted psychometric evaluation is corroborated by extensive historical reviews of Sensory Processing Disorder, which synthesize over four decades of clinical literature to underscore the necessity of aligning behavioral testing with specific biological and biomarker metrics (Galiana-Simal et al., 2020).

Method

Study Design

The article is based on a secondary conceptual and psychometric interpretation of the UNOWA Six Developmental Domains pilot report, Version 2.0. The pilot study was designed to examine the psychometric properties, reliability, validity, age sensitivity, and preliminary norms of the diagnostic instrument. The pilot also aimed to identify areas requiring refinement before full standardization.

Participants

The pilot study included 153 children aged 18–83 months. The mean age was 46.1 months, with a standard deviation of 20.3 months. The sample was divided into seven age groups: 18–23 months, 24–29 months, 30–35 months, 36–47 months, 48–59 months, 60–71 months, and 72–83+ months. The age-group distribution included 20 children in most groups, 30 children in the 36–47-month group, and 23 children in the 72–83+ group.

Table 1. Demographic Distribution of the Pilot Sample by Age Subgroups

Age Group	Number of Children (N)	Percentage of Total Sample (%)
18–23 months	20	13.07%
24–29 months	20	13.07%
30–35 months	20	13.07%
36–47 months	30	19.61%
48–59 months	20	13.07%
60–71 months	20	13.07%
72–83+ months	23	15.03%
Total (N_{total})	153	100.00%

As illustrated in Table 1, the pilot sample comprised 153 children distributed across seven distinct age bands spanning from 18 to 83+ months. The sample size was held uniform at 20 participants for the majority of the sub-cohorts, with the exceptions of the 36–47-month group (N = 30, 19.61%) and the oldest 72–83+ month group (N = 23, 15.03%), ensuring a balanced representation across early childhood developmental stages.

Instrument

The pilot instrument included five assessed domains: cognitive, social, physical, sensory, and daily living skills. Each item was scored on a 0-1-2 scale. The final domain score was calculated as a Percentage Score using the following formula: total score divided by the number of applicable items multiplied by 2, then multiplied by 100. This produced a 0–100% domain score for each child.

For the sensory domain, the interpretation was inverted. A score of 2 indicated "rare/normal" sensory manifestation, reflecting better sensory well-being, whereas a score of 0 indicated "frequent/problem" manifestation. Therefore, a higher sensory percentage did not mean "more sensory behavior," but rather greater sensory well-being or lower sensory difficulty.

Data Preparation and Quality Control

The pilot report described a stepped data structure: each child completed only the age-relevant block, while empty cells in non-applicable blocks were treated as not applicable rather than missing. The master dataset included 153 rows and 42 variables. Across the five domain scores, there were no missing values in the final domain-level variables.

The valid ranges were 24.05–100.00 for the cognitive domain, 25.83–100.00 for the social domain, 23.08–100.00 for the physical domain, 77.72–100.00 for the sensory domain, and 43.75–100.00 for the daily living domain.

Analytic Procedures

The pilot report used descriptive statistics, floor/ceiling effect analysis, Spearman correlations with age, simple linear regression, adjacent age-group comparisons using the Mann-Whitney U test and Cliff's delta, Cronbach's alpha by age block, item analysis, interdomain correlations, partial correlations controlling for age, exploratory factor analysis, and preliminary percentile norms. The present article focuses on the results most relevant to the sensory domain.

Results

Descriptive Profile of the Sensory Domain

The overall sensory domain score was high in the sample. Across all 153 children, the sensory domain had a mean of 91.83, standard deviation of 7.13, median of 91.85, interquartile range of 15.22, minimum of 77.72, and maximum of 100.00. Compared with other domains, the sensory domain had a narrower range and a higher lower bound. For example, the cognitive domain ranged from 24.05 to 100.00, the social domain from 25.83 to 100.00, the physical domain from 23.08 to 100.00, and the daily living domain from 43.75 to 100.00.

This distribution suggests that the sensory score in the pilot version may have been less sensitive at the lower end of functioning and more concentrated in the high-score range. However, because the sensory score was inverted, this high concentration may reflect a large number of children with few reported sensory difficulties, rather than advanced developmental performance. This difference is important: high sensory scores should not be interpreted in the same way as high cognitive or social scores.

Age-Group Descriptive Patterns

The sensory domain did not show a simple linear increase across age groups. Mean sensory scores were 91.74 for 18–23 months, 90.38 for 24–29 months, 92.42 for 30–35 months, 90.85 for 36–47 months, 83.83 for 48–59 months, 92.85 for 60–71 months, and 100.00 for 72–83+ months. This pattern differs from domains such as social and daily living skills, which showed clearer developmental increases across age groups.

The sensory domain's age-group pattern is theoretically meaningful. If sensory functioning were a simple developmental achievement scale, a gradual age-related increase would be expected. Instead, the score fluctuated, with a notable drop in the 48–59-month group and a ceiling in the 72–83+ group. This suggests that the current sensory score may reflect a combination of true regulatory differences, age-block item structure, and ceiling effects.

Age Sensitivity

The sensory domain showed a statistically significant but weak correlation with age: Spearman $\rho = .186$, $p = .021$. The regression coefficient was $\beta = .098$, with $R^2 = .078$. This means that age explained only a small proportion of variance in the sensory score. By contrast, the social domain showed $\rho = .830$ and $R^2 = .566$, the daily living domain showed $\rho = .649$ and $R^2 = .395$, the physical domain showed $\rho = .605$ and $R^2 = .236$, and the cognitive domain showed $\rho = .560$ and $R^2 = .347$.

Table 2. Linear Relationship Parameters with Age and Interdomain Spearman Correlation Matrix

Developmental Domain	ρ with Age	p-value	R ²	Cognitive	Social	Physical	Daily Living	Sensory
Cognitive	.560	<.05	.347	1.00	.59	—	.53	-.06
Social	.830	<.05	.566	.59	1.00	.64	.72	.13
Physical	.605	<.05	.236	—	.64	1.00	.60	.01
Daily Living	.649	<.05	.395	.53	.72	.60	1.00	-.04
Sensory	.186	.021	.078	-.06	.13	.01	-.04	1.00

Note. All general developmental domains demonstrate standard, statistically significant linear sensitivity to chronological age ($p < .05$). Em-dashes (—) represent correlation pathways that were not explicitly detailed in the preliminary pilot text dataset.

Table 2 presents the parameters of the linear regression analysis alongside the interdomain Spearman correlation matrix for the five assessed functional areas. A stark psychometric contrast emerges between the classical developmental domains and the sensory construct. While traditional skills like social socialization ($\rho = .830$, $R^2 = .566$) and daily living skills ($\rho = .649$, $R^2 = .395$) exhibit a powerful linear progression relative to age, the sensory domain shows a statistically significant but remarkably weak association with age ($\rho = .186$, $p = .021$, $R^2 = .078$). Furthermore, the interdomain correlations highlight that sensory functioning shares near-zero or weak associations with all other spheres, ranging from $-.06$ with cognition to $.13$ with social skills, reinforcing its independence.

This contrast is central to the argument of the article. The other domains behaved more like developmental domains: their scores increased substantially with age. The sensory domain behaved more like a regulatory domain: it was only weakly related to chronological age. Therefore, sensory functioning should not be interpreted primarily through the question "Is the child older and therefore better?" Instead, it should be interpreted through the question "What sensory-regulatory conditions support or disrupt this child's functioning?"

Adjacent Age-Group Comparisons

The Mann-Whitney comparisons between adjacent age groups showed a non-linear pattern in the sensory domain. Comparisons between 18–23 and 24–29 months, 24–29 and 30–35 months, and 30–35 and 36–47 months were not statistically significant. However, the comparison between 36–47 and 48–59 months showed a significant decrease, $p < .001$ with a very large negative Cliff's delta of $-.613$. The comparison between 48–59 and 60–71 months showed a significant increase, $p < .001$, with a very large effect of $.915$. The comparison between 60–71 and 72–83+ months also showed a significant increase, $p < .001$, with a very large effect of $.800$.

These results do not support a smooth developmental trajectory. Instead, they suggest that the sensory domain may be strongly affected by the structure of age blocks, item difficulty, or subgroup-specific sensory profiles. The sharp drop in the 48–59-month group is especially important because it may indicate either a problematic block of sensory items or a developmental period in which sensory demands become more visible in more complex environments.

Floor and Ceiling Effects

The pilot report defined a hard ceiling/floor as more than 15% of children scoring 100% or 0%, and a soft ceiling/floor as more than 20% of children scoring $\geq 95\%$ or $\leq 5\%$. The sensory domain showed no floor effect at the domain level, but it showed notable ceiling effects in several age groups. The percentage of children with exactly 100% in the sensory domain was 40.0% in the 18–23-month group, 30.0% in the 24–29-month group, 30.0% in the 30–35-month group, 13.3% in the 36–47-month group, 0.0% in the 48–59-month group, 20.0% in the 60–71-month group, and 100.0% in the 72–83+ group. The soft ceiling pattern was also notable: the percentage of children scoring $\geq 95\%$ in the sensory domain was 45.0% in the 18–23-month group, 30.0% in the 24–29-month group, 40.0% in the 30–35-month group, 40.0% in the 36–47-month group, 0.0% in the 48–59-month group, 40.0% in the 60–71-month group, and 100.0% in the 72–83+ group.

These results indicate that the sensory domain requires further psychometric refinement. However, they also support the idea of sensory heterogeneity: some children appear to have very few sensory difficulties, while others show lower sensory well-being. A single global sensory score may be insufficient to capture this diversity.

Reliability

Cronbach's alpha for the sensory domain varied substantially across age blocks. The sensory system showed $\alpha = .934$ in the 18–23-month group, $\alpha = .899$ in the 24–29-month group, $\alpha = .893$ in the 30–35-month group, $\alpha = .867$ in the 36–47-month group, $\alpha = .172$ in the 48–59-month group, $\alpha = .851$ in the 60–71-month group, and no computable alpha in the 72–83+ group because of insufficient variability.

This pattern shows that the sensory domain had good to excellent internal consistency in several age groups, but a severe reliability problem in the 48–59-month block and no meaningful variability in the oldest group. This finding is important because it prevents an oversimplified conclusion. The sensory domain is not uniformly weak. In several age groups, it appears internally consistent. However, specific age blocks require substantial revision. The 48–59-month group is particularly important because it combines a lower mean sensory score with very low internal consistency.

Table 3. Reliability Metrics and Distribution of Ceiling Effects for the Sensory Domain Across Age Blocks

Age Block	Hard Ceiling (% scoring exactly 100%)	Soft Ceiling (% scoring $\geq 95\%$)	Cronbach's Alpha (α)
18–23 months	40.0%	45.0%	.934
24–29 months	30.0%	30.0%	.899
30–35 months	30.0%	40.0%	.893
36–47 months	13.3%	40.0%	.867
48–59 months	0.0%	0.0%	.172
60–71 months	20.0%	40.0%	.851
72–83+ months	100.0%	100.0%	\$a\$

Note. α = Cronbach's alpha was uncomputable due to zero variance within this specific age block.

The block-specific psychometric properties of the sensory construct are detailed in Table 3. The instrument demonstrated good to excellent internal consistency across most age cohorts, with Cronbach's alpha values ranging from .851 to .934. However, a severe psychometric anomaly is localized within the 48–59-month age block, where internal consistency collapses to $\alpha = .172$, coinciding with a complete absence of both hard and soft ceiling effects (0.0%). Conversely, the oldest cohort (72–83+ months) exhibited an absolute ceiling profile (100.0%), resulting in zero item variance and rendering the alpha coefficient uncomputable.

Item Analysis

The item analysis showed that the sensory domain requires substantial refinement. Across the pilot dataset, 644 sensory items were analyzed and all 644 were flagged as problematic according to the pilot report's criteria, which included low item-total correlation and/or excessive floor/ceiling effects. This does not mean that every item is conceptually invalid. Rather, it indicates that the current item pool, when analyzed across age blocks and scoring patterns, does not yet provide sufficient discrimination for full standardization.

For a sensory construct, such a result is not surprising. Sensory functioning is not a single homogeneous trait. Items may reflect different sensory modalities, response types, thresholds, contexts, and regulatory strategies. A child may be auditory-sensitive but tactile-seeking; another may be vestibular-seeking but visually overwhelmed; another may show low registration rather than avoidance. If all such items are collapsed into a single score, item discrimination may appear weak because the latent structure is multidimensional.

Interdomain Correlations

The interdomain Spearman correlation matrix showed that the cognitive, social, physical, and daily living domains were moderately to strongly related. Cognitive functioning correlated with social functioning at .59 and with daily living at .53. Social functioning correlated with physical functioning at .64 and daily living at .72. Physical functioning correlated with daily living at .60. These results suggest a coherent functional-developmental cluster.

By contrast, the sensory domain had weak or near-zero correlations with the other domains: -.06 with cognitive, .13 with social, .01 with physical, and -.04 with daily living. After controlling for age, the sensory domain remained relatively independent and showed negative partial correlations with cognitive functioning, physical functioning, and daily living. Specifically, the partial correlation between sensory and cognitive was -.20, between sensory and physical was -.14, and between sensory and daily living was -.21.

These findings strongly support the interpretation of sensory functioning as a distinct construct. The sensory score does not simply duplicate cognitive, social, physical, or daily living performance. It contributes unique information to the child's profile.

Exploratory Factor Analysis

Exploratory factor analysis provided the strongest structural evidence for the distinct status of the sensory domain. The EFA was conducted using principal axis factoring on 153 observations across the five domain scores. The Kaiser-Meyer-Olkin value was .775, indicating acceptable factorability, and Bartlett's test of sphericity was significant, $\chi^2 = 303.43$, $p < .001$.

In the one-factor solution, the cognitive, social, physical, and daily living domains loaded substantially on the general factor, while the sensory domain had almost no loading. The one-factor loading for the sensory domain was -.028, with communality of .001. By contrast, social and daily living had loadings above .90, and physical had a loading above .80.

In the two-factor oblimin solution, the sensory domain loaded strongly on a separate factor. The sensory domain had a loading of .966 on Factor 2 and communality of .934. The social, physical, and daily living domains loaded strongly on Factor 1, while sensory remained separate. This is the clearest psychometric evidence that the sensory domain should not be treated as merely another indicator of the general developmental factor.

Discussion

Sensory Functioning as a Regulatory Construct

The UNOWA pilot results support the interpretation of sensory functioning as a regulatory construct rather than a simple developmental achievement scale. Developmental achievement domains answer the question: What can the child do? Regulatory domains answer a different question: Under what conditions can the child remain organized enough to do what they can do?

This distinction is essential. A child may have adequate cognitive capacity but may not demonstrate it in a noisy or overstimulating environment. A child may have social interest but may avoid interaction when tactile or auditory demands are too high. A child may have physical ability but may become disorganized during transitions or when vestibular input is unpredictable. A child may have daily living skills but may refuse hygiene or feeding routines because of texture, sound, smell, or body-boundary discomfort.

In such cases, the sensory domain does not measure a secondary symptom. It measures the regulatory conditions that determine whether other skills can be expressed. Therefore, the sensory score should be interpreted as a functional access variable: it shows whether the child can access learning, communication, social participation, and adaptive behavior under real environmental conditions.

Impact on Adaptive Behavior and Developmental Trajectories

Longitudinal evidence indicates that early sensory response patterns predict later adaptive behavior. In children with ASD and other developmental disabilities, hyperresponsiveness, hyporesponsiveness, and sensory seeking all significantly predicted aspects of adaptive functioning from mean age 5.6 to 9.0 years, with elevated early sensory features linked to lower later adaptive skills (Williams et al., 2018). A broader review similarly notes that sensory features in autism have cascading developmental effects and functional impact on adaptive behavior, social participation, and well-being (Baranek et al., 2014).

In a mixed neurodevelopmental cohort, sensory subtypes showed distinct regulatory risks: the Over-Responsive group had elevated anxiety, the Seeking and Under-Responsive groups elevated ADHD symptoms, and all three atypical subgroups showed higher emotion dysregulation, suggesting shared mechanisms linking sensory differences to emotional and attentional problems (Brandes-Aitken et al., 2024).

At the population level, sensory features in autism are associated with difficulties in adaptive behavior and multiple co-occurring domains (emotional states, aggression, attention, fear, motor, eating, sleeping), independent of cognitive level, underscoring their broad functional significance (Kirby et al., 2022).

Differentiating Developmental and Regulatory Domains

The pilot findings support a distinction between developmental domains and regulatory domains. Cognitive, social, physical, and daily living scores were more strongly associated with age and with one another. These domains appear to reflect skill acquisition and functional maturation.

Sensory functioning was only weakly related to age, weakly related to other domains, and structurally separate in EFA. It appears to reflect a different layer of child functioning.

This distinction does not mean that sensory functioning does not develop. Rather, it means that sensory functioning may not develop in a linear, age-dependent way. It may be affected by nervous system maturation, environmental demands, stress, sleep, family routines, educational context, therapy, and the child's individual sensory thresholds. Therefore, sensory functioning should be interpreted as a profile, not merely as a level.

Implications for Inclusive Education

In inclusive educational settings, sensory assessment can prevent misinterpretation of behavior. Children with sensory vulnerabilities may be described as disobedient, inattentive, unmotivated, oppositional, or emotionally unstable. However, a sensory-regulatory interpretation may show that the child is responding to overload, unpredictability, excessive stimulation, insufficient proprioceptive input, or difficulty switching between contexts.

This has practical consequences. If the sensory profile indicates auditory sensitivity, the support plan may include reduced noise, headphones, smaller groups, or visual instructions. If the profile indicates tactile avoidance, the plan may include alternative materials, gradual exposure, or predictable hygiene routines. If the profile indicates sensory seeking, the plan may include movement breaks, heavy work, structured body-based activities, or adaptive seating. If the profile indicates difficulty with switching, the plan may include transition warnings, visual sequences, and predictable routines. Ultimately, such targeted frameworks demonstrate that the core utility of structured assessment lies not in rigid typologization or labeling, but in identifying stable configuration patterns to form a non-clinical analytical layer for differentiated support (Drobakha et al., 2026).

Interventions Targeting Sensory Functioning and Related Outcomes

Ayres Sensory Integration and Sensory-Based Interventions

The therapeutic landscape addressing these sensory vulnerabilities contains critical distinctions between highly structured, child-directed regimens and isolated classroom modifications. Methodological reviews evaluating Ayres Sensory Integration (ASI) protocols for autistic cohorts (ages 4–12) against strict Council for Exceptional Children metrics show that high-fidelity, clinic-based ASI implementations function as validated, evidence-based practices that effectively stimulate adaptive neurological reorganization (Schoen et al., 2018).

In contrast, broader systematic analyses spanning research from 2000 to 2012 reveal a clear split in efficacy: while classic sensory integration therapies consistently achieved marked improvements in Goal Attainment Scaling (effect sizes .72–1.62) along with corresponding drops in maladaptive behavior, generic sensory-based interventions (SBIs)—including weighted vests or stability balls—demonstrated negligible positive outcomes, frequently failing to align with recommended delivery protocols or directly target verified sensory vulnerabilities (Case-Smith et al., 2015).

This distinction is further clarified by recent systematic reviews covering sensory interventions from 2015 to 2024, which report robust empirical support for localized deep pressure tactile inputs and structured caregiver sensory training, but find moderate evidence that alternative seating modifications fail to enhance attention; notably, multi-system interventions consistently outperform single-system approaches, whereas data confirming the value of isolated environmental modifications remain sparse (Piller et al., 2025).

To maximize efficacy, modern state-of-the-art syntheses recommend highly integrated, multidisciplinary frameworks that combine foundational sensory integration therapies, advanced behavioral and mindfulness-based methodologies, and emerging neuroplasticity-oriented strategies such as neurofeedback or non-invasive brain stimulation, explicitly tailored to the child's verified sensory profile (Consoli et al., 2025).

Early Intervention and Multisensory Environments

The absolute necessity of merging structured sensory strategies with traditional developmental frameworks is strongly supported by randomized controlled trials examining enriched early interventions. For instance, evaluation of the GAME (Goal Activity and Motor Enrichment) protocol in delayed toddlers (24–36 months) established that a combined clinic-and-home program generated significantly superior outcomes over isolated home programs across all Bayley-III subscales, the PICCOLO parent-child interaction index, and the ASQ motor and socio-emotional subscales, while concurrently fostering highly organized, normative processing profiles on the Infant/Toddler Sensory Profile-2 (Gündoğmuş et al., 2024).

Concurrently, pilot randomized trials exploring Multisensory Environments (MSEs, such as specialized Snoezelen facilities) in preschool ASD groups reveal that augmenting Treatment-As-Usual (TAU) with targeted MSE sessions yields significant improvements in taste, smell, and tactile processing habits on the CARS-2 index alongside gross motor advances on the PEP-3, suggesting a valuable pathway for self-managing sensory thresholds (De Domenico et al., 2024).

Ultimately, this body of intervention literature emphasizes that comprehensive, multi-system, and fidelity-monitored systems—including deep pressure methods, direct caregiver coaching, and clinic-based ASI—possess vastly superior empirical foundations compared to isolated, poorly targeted sensory add-ons (Case-Smith et al., 2015; Piller et al., 2025).

Implications for HumanAI UNOWA

The sensory domain has particular value for future AI-assisted interpretation within the HumanAI UNOWA framework. If AI receives only global developmental scores, it can generate a general developmental profile. However, if sensory functioning is modeled as a distinct regulatory profile, AI can identify patterns that are more clinically and educationally meaningful.

For example, HumanAI UNOWA could identify a child with strong cognitive performance but low sensory well-being and recommend modifying environmental conditions rather than simplifying cognitive tasks. It could identify a child whose daily living difficulties are associated with sensory avoidance and recommend gradual work with textures, sequences, and routines. It could identify a child whose social difficulties are intensified by sensory overload and recommend environmental regulation before social-skills training.

Thus, sensory functioning can become a decision-making layer. It can help determine not only what should be taught, but how the environment should be structured so that teaching becomes possible. As these intelligent diagnostic ecosystems evolve, their structural design increasingly intersects with broader paradigms of digital code architectures and systematic human-machine interaction frameworks, which are critical when conceptualizing operational boundaries and individual tracking profiles in advanced digital environments (Kostenko & Zhuravlov, 2025).

Limitations

The pilot findings should be interpreted cautiously. First, the study was preliminary and included limited sample sizes in some age groups. Second, no test-retest data were available, so temporal stability could not be evaluated. Third, external validity has not yet been tested against established sensory assessment instruments. Fourth, the sensory item pool showed substantial psychometric limitations, including low item discrimination and ceiling/floor effects. Fifth, the global sensory score may mask distinct sensory patterns that require separate subscales.

These limitations do not undermine the value of the pilot. Instead, they identify the next stage of development. The current results show that sensory functioning is psychometrically and conceptually distinct enough to justify a separate model.

Future Directions

Links to Broader Developmental Frameworks and Future Directions

The expansion of the sensory-focused UNOWA architecture aligns with broader international movements that utilize big-data analytics and large-scale psychometric validation to engineer globally harmonized assessment instruments, as demonstrated by the GSED and CREDI initiatives (McCray et al., 2023; Waldman et al., 2021). By demonstrating that sensory profiles accurately describe the core environmental conditions necessary for behavioral organization, participation, and learning rather than isolated linear skills, the UNOWA pilot establishes an essential layer for future AI-driven interpretive systems (Kalitkin, 2026).

Furthermore, comprehensive scientometric mapping of the sensory processing field identifies critical research priorities that subsequent iterations of the UNOWA tool must address, specifically integrating EEG-based biological markers, refining classroom environmental adaptations, and participating in long-term longitudinal effectiveness studies (Alotaibi et al., 2025). Crucially, future standardization efforts must echo the recommendations of recent global reviews by conducting rigorous measurement invariance testing to minimize structural and geographic bias within international assessment frameworks (Bliznashka et al., 2025).

Sensory-Specific Assessment Frameworks

To achieve this integration, the UNOWA system draws important lessons from established specialized instruments such as the Sensory Processing Measure (SPM), whose extensive clinical application across age ranges demonstrates the utility of mapping unique sensory thresholds onto everyday academic and functional challenges (Alotaibi et al., 2025).

As supported by comprehensive reviews of sensory processing phenotypes in neurodevelopmental disorders, future editions of the UNOWA instrument must transition away from a single composite score toward independent subscales that meticulously capture hyperresponsiveness, hyporesponsiveness, and active sensory seeking patterns (Baranek et al., 2014; Galiana-Simal et al., 2020).

Consequently, future versions of the UNOWA assessment will differentiate the sensory domain into specific subcomponents. At minimum, the sensory profile will include subscales for sensory hyperresponsivity, sensory hyporesponsivity, sensory seeking, sensory avoidance, switching, activation, passivity, and self-regulation. This structure will allow the system to distinguish between different sensory mechanisms that may produce similar behavioral outcomes.

The next standardization stage should include larger samples, preferably at least 50 children per age group. Test-retest reliability should be assessed over a 2–4 week interval. External validity should be examined by comparing the UNOWA sensory domain with established sensory measures. Factor analysis should be repeated after item revision to determine whether the proposed sensory subcomponents are empirically supported. Clinical and nonclinical samples should also be compared, including children with autism spectrum disorder, ADHD, language delay, intellectual disability, and sensory modulation difficulties.

Conclusions

The sensory domain in the UNOWA Six Developmental Domains pilot study should be interpreted as a distinct regulatory construct rather than as a simple age-linear developmental scale. The evidence is consistent across several levels: weak age association, weak interdomain correlations, separate factor loading, ceiling/floor effects, and item-level heterogeneity. Sensory functioning appears to describe the conditions under which a child can remain organized, participate, communicate, learn, and adapt.

This interpretation has direct implications for inclusive education, early intervention, individualized support planning, and AI-assisted developmental assessment. Sensory functioning should not be reduced to a secondary symptom or a general maturity score. It should be treated as a separate regulatory profile that helps explain how the child interacts with the environment and what type of support is needed for real participation.

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