Effects of Gradual Reintroduction of Visual Architectural Distractors on Sensory Profiles and Visual Attention in Children with Autism: An Innovation in Sensory Integration Therapy, a pilot study

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Submitted: 2025-06-18; **Accepted**: 2025-9-16; **Doi:** https: doi.org. 10.22037/jcpr. v10i1.50883

Abstract

Background: Objective measures such as eye tracking offer promise to quantify attention modulation. We report a controlled intervention in which visual distractors in the therapy room were removed and then systematically reintroduced, examining changes in sensory profiles and eye-tracking metrics. **Methods:** Five children with ADHD were enrolled in intervention group and 5 as controls. At baseline, all participants completed the Short Sensory Profile-2 (SSP-2) and an eye-tracking session to detect primary visual distractors. During a first 3-month, all distractors were removed in both groups, and standard therapy proceeded. After 3 months, all assessments were repeated. In the intervention group, over the next 3 months, architectural distractors were gradually reintroduced (one every 3 weeks) while the control group remained in the distraction-free environment. At the end of 6 months, SSP2and eye tracking were reassessed and compared. **Results:** In the intervention group, mean total SSP2score improved) from 130 ± 8 at baseline to 145 ± 10 after the first 3 months (p = 0.02), then declined modestly to 138 ± 9 after the second 3 months (p = 0.04). Eye-tracking metrics showed significant reductions in distractor engagement in the second period relative to the midpoint (p<0.03). The control group showed continued gradual improvement in SSP2 (128 ± 7 → 135 ± 9 → 140 ± 10) but no major change in distractor zone metrics. The net SSP2change in intervention group attenuated compared to control (p = 0.04). **Conclusions:** Findings support the use of eye tracking as an objective outcome measure in sensory-based interventions and highlight the importance of environmental control in autism therapy. Larger controlled trials are needed.

Keywords: Autism, Sensory Integration, Eye Tracking System, Architecture

***Please cite this paper as*:** Mehrshahi.S, Mirzakhani N. Effects of Gradual Reintroduction of Visual Architectural Distractors on Sensory Profiles and Visual Attention in Children with Autism: an Innovation in Sensory Integration Therapy, a pilot study. J Clin Physio Res. 2025; 10(1): e100. Doi: https: doi.org. 10.22037/jcpr. v10i1.50883

Introduction

Autism spectrum disorder (ASD) is characterized by persistent challenges in social communication, restricted interests, and repetitive patterns of behavior, often influenced by atypical sensory processing. Many children with ASD show hyper-responsiveness, hypo-responsiveness, or sensory-seeking patterns across visual, auditory, tactile, and proprioceptive modalities [1,2]. These sensory differences are now included as a core diagnostic feature of ASD, reflecting their central role in shaping behavioral presentation and everyday functioning. Sensory processing challenges can negatively affect attention, emotional regulation, play, social participation, and learning opportunities, both in natural environments and structured therapy settings. Occupational therapy commonly uses sensory integration interventions to support children with ASD by facilitating improved modulation and organization of sensory input [3-5].

Although widely practiced, sensory integration therapy demonstrates variability in outcomes due to differences in intervention fidelity, measurement tools, and environmental constraints. Emerging perspectives highlight that the effectiveness of sensory integration-based approaches may partially depend on characteristics of the therapy environment, such as the presence or absence of visually stimulating objects.

Therapy rooms are often filled with motivating toys, posters, shelves, and colorful decorations intended to create a playful and engaging space. However, for children with ASD, these same features can become potent and uncontrollable visual distractors that interfere with the child's attention to therapist-directed tasks. Autistic individuals frequently exhibit difficulties disengaging attention from non‑relevant stimuli, especially when such stimuli are salient or embedded in the peripheral field of view [6-8]. Sabatos DeVito et al. demonstrated that attentional disengagement is slowed when competition from irrelevant visual stimuli increases [6], and Zhang et al. reported that parafoveal distractors disrupt eye movement control in children with ASD [7]. These findings imply that the visual structure of therapy settings may be critical to therapeutic success.

Eye‑tracking technology has become an increasingly important research and clinical assessment tool for quantifying visual attention, fixation patterns, and perceptual processing in ASD [9-11]. Unlike subjective rating scales, eye tracking provides objective, continuous, and fine-grained indicators of attentional allocation across regions of interest. In autism research, eye tracking is widely used to study social attention, gaze-following, and sensory driven atypicalities [9]. Recent work has advocated incorporating eye‑tracking outcomes into intervention studies to better capture mechanisms of change and evaluate the effectiveness of therapy approaches [10,11]. Importantly, eye‑tracking measures have shown strong associations with clinical symptoms and caregiver-reported functional attention in ASD populations.

The Short Sensory Profile-2 (SSP2) is a standardized caregiver-report instrument that measures sensory processing patterns and supports identification of sensory subtypes in ASD [12,13]. However, caregiver‑reported changes may be influenced by expectations or subjective factors. Combining SSP2 with objective measures like eye tracking may improve reliability and offer a more precise understanding of sensory‑attention relationships.

Despite advances in sensory research, few studies have directly manipulated the visual environment of therapy rooms to examine how changes in distractor presence influence sensory adaptation and attentional control over time. Classroom‑based studies show that visually simplified environments can facilitate focus and task engagement for children with ASD [14,17], suggesting that similar principles in therapy sessions could optimize learning conditions. Yet, the optimal strategy for reintroducing environmental complexity, so that children can eventually function effectively in real‑world contexts, remains unclear.

This study explores a novel environmental intervention strategy that involves removing visual distractors from therapy spaces for an initial period, followed by gradual reintroduction of these distractors. By using both caregiver‑reported (SSP2) and objective (eye tracking) measures, the present controlled case study aims to provide insight into how therapy environment design influences sensory outcomes and gaze behavior in ASD. We hypothesized that (1) removal of visual distractors would lead to measurable improvements in sensory processing and decreased gaze toward distractor zones, (2) reintroducing distractors would partially reverse these improvements, and (3) a control group that remained in distraction‑free therapy spaces would continue to improve without experiencing regression.

Understanding how environmental manipulation affects sensory regulation and attention in ASD has meaningful implications for therapeutic architecture design, clinical decision‑making, and future research seeking to optimize sensory-based interventions.

Material and Methods

Participants

We recruited ten children (all male) diagnosed with autism spectrum disorder, aged 6 to 9 years (mean 7.2 ± 1.1 years). Five children were assigned to the intervention group, and five to a control group matched on age, IQ range (all ≥ 70), and baseline SSP2total score (mean 130 ± 8). Children were selected from a rehabilitation center, and inclusion criteria included stable therapy regimen (no changes in core interventions in the prior 6 months), no co-occurring neurological or sensory impairment (e.g. uncorrected vision, hearing loss), and the ability to complete eye-tracking calibration. All parents provided informed consent.

The intervention group was selected such that their primary distractor(s), as determined in a prior mapping session, were broadly similar (e.g. colorful wall posters, toy shelves) to allow consistency in reintroduction.

Design

This was a quasi-experimental, repeated-measures intervention with two periods of 3 months each:

- Period 1 (Months 0-3): For both groups, all identified visual distractors in the therapy room were removed; therapy continued as usual in a cleaner environment.

Midpoint assessment (after 3 months): SSP2and eye tracking.

- Period 2 (Months 3-6): In the intervention group, distractors were gradually reintroduced (one every 3 weeks, total of 4 distractors over 12 weeks). The control group continued therapy in distractor-free settings.

- Final assessment (after 6 months): SSP2 and eye tracking repeated.

Dependent Variables

Short Sensory Profile-2 (SSP2)

The SSP2is a caregiver-report measure assessing sensory behaviors across quadrants (seeking, registration, sensitivity, avoiding) and yields a total score (higher = more normative/less impairment). It has been used to cluster sensory subtypes in ASD populations [2, 14].

Eye-tracking

We used a desktop eye-tracking system (sampling rate 60 Hz, spatial accuracy ~0.5°) in a standardized calibration protocol. In each session, children sat at a fixed distance (60 cm) and viewed the therapy room scene on a calibrated display, with known regions of interest corresponding to potential distractor zones (e.g. poster area, shelf area). For the mid and final assessments, we additionally used the heatmap-derived metrics to identify which distractor zones (if any) attracted the strongest gaze cluster (i.e. the main “visual distractor zone”). Key eye-tracking metrics including: fixation count within the distractor zone ROI, average dwell time on the distractor ROI per fixation, total dwell time in distractor zone (sum over fixations) and proportion of total fixations falling in distractor ROI, were computed. These metrics were compared across mid and final stages, and relative to baseline mapping.

Intervention Implementation

During Period 2, distractors were reintroduced in a controlled, phased manner:

- At week 0 of Period 2, none were present.
- At week 3, Distractor A was introduced (e.g. a wall poster).
- At week 6, Distractor B (e.g. a small shelf with toys).
- At week 9, Distractor C (e.g. wall-mounted picture frames).

Each new distractor remained in place once introduced, so by week 9 all four were present. Therapies continued identical to Period 1 in content, duration, and schedule.

Statistical Analysis

Table 1. SSP2 Total Scores Over Time (Mean ± SD)

Group	Baseline	Midpoint (3	Final (6	Change 0-3	Change 3-6
Intervention	130 ± 8	145 ± 10	138 ± 9	+15 (p= 0.02)	-7 (p=0.04)
Control	128 ± 7	135 ± 9	140 ± 10	+7 (P= 0.05)	+5 (P= 0.08)

Table 2. Distractor-ROI Eye-Tracking Metrics In Intervention Group (Mid Vs Final)

Metrics	Midpoint (3 mon)	Final (6 mon)	Change (Δ)	P-value
Fixation counts (n)	150 ± 12	110 ± 15	-40	P= 0.03
Average dwell time (ms)	320 ± 40	280 ± 35	-40	P= 0.04
Total dwell time (ms)	48000 ± 4.800	30800 ± 3.500	-17.200	P= 0.02
Proportion of fixations (%)	225 ± 3.0	16.5 ± 2.8	-6.0	P= 0.03

Because of the small sample size, we used nonparametric paired tests (Wilcoxon signed-rank) for within-group comparisons (e.g. SSP2 at baseline → mid → final) and Mann Whitney U tests for between-group comparisons on change scores. The effect sizes were also computed and the significance threshold was set at $\alpha = 0.05$ for all statistical procedures. The first-period gains (baseline → mid) and the second-period changes (mid → final) within and between groups were also analyzed.

Results

SSP2 Changes (Table 1)

In the intervention group, the increase from baseline to 3 months was statistically significant ($p = 0.02$, $r = 0.67$). The subsequent decline (mid → final) of 7 points was also significant ($p = 0.04$, $r = 0.60$). The control group showed a moderate improvement over the full 6 months, though the second phase change (mid → final) was not significant ($p = 0.08$). Between-group comparison of second-phase change (-7 vs +5) yielded $p = 0.04$ (Mann-Whitney), suggesting a statistically significant difference in pattern of change.

Eye-Tracking Metrics

After reintroduction, all distractor metrics declined, indicating reduced engagement with the introduced distractors. For example, fixation count dropped by ~27% (150 → 110). The proportion of total fixations falling in that ROI fell from 22.5% to 16.5%. In the control group, distractor metrics remained negligible (mean fixation count ≈ 5 ± 3, dwell time ≈ 1,200 ± 800 ms) across both periods (no significant changes).

Discussion

This pilot-controlled intervention provides emerging evidence that the visual architecture of therapy settings plays a critical and modifiable role in shaping sensory and attentional outcomes in children with autism spectrum disorder (ASD). When visual distractors were removed for three months, children demonstrated notable improvements in sensory processing as reflected by SSP2scores, alongside measurable reductions in distractor-related gaze. The subsequent reintroduction of these visual elements partially diminished initial gains, illustrating the sensitivity of autistic sensory and attentional systems to changes in environmental complexity.

These results align with contemporary theories suggesting that sensory difficulties in ASD may be amplified by external “sensory noise,” particularly within visually stimulating contexts [3,5]. By minimizing clutter and visual competition, the simplified environment may reduce cognitive load and allow children to focus more effectively on therapeutic demands, leading to more efficient sensory integration. The small regression observed after reintroducing distractors further supports the idea that sensory and attentional mechanisms in ASD require gradual exposure and adaptive pacing when returning to more complex, real-world environments.

Eye-tracking metrics in this study offer an objective complement to caregiver-rated outcomes. Reduced fixation frequency and dwell time in distractor zones serve as direct indicators of improved visual attentional control. When distractors returned, eye-tracking indices changed in the predicted direction, reflecting renewed but not complete distractibility. This suggests that children did not fully revert to baseline attentional profiles, implying some retention of coping or regulation strategies developed during the distractor-free phase. Convergence between SSP2and gaze outcomes strengthens confidence in the interpretation of true intervention-related responses rather than expectancy or rater bias.

Our findings reinforce decades of evidence showing that autistic individuals experience slowed or impaired attentional disengagement, particularly when irrelevant stimuli are highly salient or spatially prominent [6-8,16]. When therapy environments contain excessive visual stimuli, children with ASD may struggle to reallocate attention to therapist-led tasks, leading to reduced engagement and therapeutic efficacy. Eye tracking has been advocated as a promising metric for capturing such attentional dynamics [10,11], and our study demonstrates its sensitivity to environmental manipulation.

Environmental design principles are increasingly emphasized in autism education and intervention research. Studies in classroom contexts suggest that reducing visual clutter improves on-task performance and participation [14,17]. Our phased reintroduction approach builds upon this work and more closely mirrors the practical challenge clinicians face—balancing sensory accommodations with the need for exposure to real-world complexity. The observed partial decline during reintroduction may reflect insufficient time for adaptive generalization, underscoring the importance of individualized pacing. A slower, more personalized reintroduction schedule might allow children to consolidate attentional strategies more fully before facing additional environmental demands.

Notably, the interaction between sensory processing and attentional control is not uniform across autistic individuals. Crasta et al. demonstrated substantial variability in how attention modulates sensory responsiveness [16]. In our sample, children with greater reductions in distractor-directed gaze tended to retain more of their sensory gains, hinting at a protective role of attentional control in sustaining therapeutic improvements. Future studies with larger samples should formally investigate whether specific sensory profiles or attentional characteristics predict responsiveness to environmental modifications.

Another relevant issue concerns the debated efficacy of sensory integration (SI) interventions in ASD. While some systematic reviews support SI-based approaches [3-5], others point to inconsistent methods and unclear mechanisms [18]. By incorporating objective, performance-based measures like eye tracking, studies such as ours may help clarify mechanisms and better define the specific conditions under which SI strategies are most beneficial. Our results suggest that the environmental context may be a critical determinant of therapeutic impact and thus should be considered a core component of SI fidelity.

Finally, incorporating architectural considerations in therapy design aligns with universal design principles and occupational therapy models that emphasize matching environmental demands to individual capabilities. Ultimately, intervention effectiveness may depend not only on the therapeutic techniques employed, but also on whether the environment reduces stress, minimizes distraction, and fosters engagement.

Limitations

- Sample size: Only n = 5 per group limits statistical power, generalizability, and reliability of correlation estimates.
- Non-random assignment: Groups were matched but not randomized, which introduces potential selection bias.
- Potential carryover and expectancy effects: Caregivers' awareness of intervention could influence SSP2reporting.
- Restricted generalizability: The types of distractors and architecture are limited to this center; results may differ in other settings or with auditory/tactile distractors.
- Temporal span: Six months is still a relatively short duration for sustained adaptation.
- Calibration and measurement error in eye-tracking (e.g. head movement) could affect metrics.
- No behavioral performance data: We did not concurrently measure functional task performance (e.g. therapy outcomes) or generalization outside the environment.
- Ceiling/floor effects: Some children might already show minimal distractor gaze at baseline; such cases are less sensitive to change.

Conclusion

In this controlled case intervention, we provide preliminary evidence that maintaining a distractor-free therapy environment enhances sensory integration gains in children with ASD, and that gradual reintroduction of visual architectural distractors can attenuate those gains, paralleled by increased gaze toward distractors. The use of eye tracking as an objective marker offers promise in quantifying intervention effects. These results underscore the importance of environmental design in autism therapy and the need for controlled studies on environmental manipulations.

Acknowledgment
We express our deep gratitude to the children and families who participated in this study, and to the therapists and staff at the rehabilitation center for their collaboration and patience.

Ethical consideration
Ethical approval was obtained from the Research Ethics Committee of the Shahid Beheshti University of Medical Sciences (code: IR.SBMU.RETECH.REC.1404.298)

Funding support
This research did not receive any grants from funding agencies in the public, commercial, or non-profit sectors.

Conflict of interest
None.

Authors' contributions
All authors contributed equally to the preparation of this article.

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