ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202512_8(12).0016

Sensory Regulation–Based Classroom Strategies for Reducing Anxiety and Behavioral Challenges in Children with Autism: A Pragmatic Cluster-Randomized Trial

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Abstract

Anxiety and behavior dysregulation are common barriers to learning for students with ASD. Sensory over-responsivity and state regulation challenges often increase classroom stressors. While sensory-based supports are commonly utilized in schools, few rigorous, classroom-level studies with implementation detail exist. We conducted a pragmatic, cluster-randomized controlled trial across 36 elementary classrooms (grades 1–4) in inclusive and specialized settings. Classrooms were randomized 1:1 to a 12-week Sensory Regulation Classroom Package (SRCP) or business-as-usual (BAU). SRCP comprised six components: (1) environmental zoning with low-stimulation "calm corners"; (2) brief, scheduled proprioceptive/vestibular "sensory-diet" breaks; (3) visual interoceptive self-monitoring tools; (4) soundscaping with steady-state noise dampening; (5) movement-integrated transition routines; and (6) teacher training with weekly coaching and fidelity checks. Participants were 216 students with autism (mean age 8.4 years; 72% male). The primary outcome was teacher-rated school anxiety (School Anxiety Scale–Teacher Report; SAS-TR) at 12 weeks. Secondary outcomes included irritability (Aberrant Behavior Checklist–Irritability, ABC-I), off-task behavior (proportion of interval-coded minutes), meltdown frequency (count per week), and heart rate variability (RMSSD). Assessments occurred at baseline (T0), 6 weeks (T1), 12 weeks (T2), and 8-week follow-up (T3). Intention-to-treat analyses used mixed-effects models with random intercepts for classroom and student. Prespecified mediation tested whether changes in sensory modulation (Sensory Profile–School Companion index) explained anxiety reduction. Baseline characteristics were balanced. Intervention fidelity averaged 86% (SD 9). At 12 weeks, SRCP yielded lower SAS-TR scores than BAU (adjusted mean difference -3.8, 95% CI -5.4 to -2.2; standardized d = 0.45). Clinically meaningful anxiety improvement (≥20% reduction) occurred in 49% of SRCP vs 27% of BAU students (risk ratio 1.81; number needed to treat ≈ 5). Secondary outcomes favored SRCP: ABC-I decreased (-5.2 points, 95% CI -7.4 to -3.0), off-task behavior decreased by 21% (relative), meltdown frequency fell (incidence rate ratio 0.66, 95% CI 0.54-0.81), and RMSSD increased (+12 ms, 95% CI +6 to +18). Benefits persisted at T3 with partial attenuation. Mediation analysis indicated that 38% (95% CI 22–56) of the anxiety reduction was explained by improved sensory modulation. Effects were larger in students with baseline sensory over-responsivity and in classrooms with higher ambient noise. No serious adverse events occurred. A low-cost, multicomponent sensory regulation package improved anxiety and behavior outcomes in elementary classrooms serving students with autism. Gains were partially mediated by better sensory modulation, supporting a mechanistic pathway from environmental and proprioceptive supports to arousal regulation and functional behavior. Pragmatic implementation with coaching and fidelity monitoring appears feasible and beneficial.

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Keywords

Autism spectrum disorder; School anxiety; Behavior regulation; Sensory integration; Randomized trial; Implementation.

1. Introduction

Anxiety and behavioral dysregulation interfere with academic engagement and peer participation for many children on the autism spectrum. The dynamic sensory demands of crowded hallways [1], variable lighting, unpredictable noise, and frequent transitions in school can trigger physiological arousal that, in turn, fosters escape-maintained behaviors, off-task time, and meltdowns. Challenges of this nature are by no means epiphenomenal; they are often a reflection of how the mismatch between environmental input and a child's capacity for sensory modulation and interoceptive awareness plays out in education [2]. Classrooms, therefore, represent both a context of risk and an opportunity for systematic, preventative regulation.

Sensory-responsive supports are implemented in schools worldwide, yet the evidence base for classroom-level packages-particularly those that blend environmental modification [3], planned proprioceptive/vestibular input, and self-monitoring-remains limited by small samples, heterogeneous components, and weak implementation reporting. Practical barriers include teacher workload, uncertainty about "what to do when," and lack of fidelity feedback [4]. Few, moreover, investigate mechanistic pathways linking sensory regulation to anxiety and real-time behavior in authentic school routines.

This pragmatic cluster-randomized trial evaluated a Sensory Regulation Classroom Package (SRCP) designed to be feasible for teachers with brief training and weekly coaching. We hypothesized that SRCP would reduce school anxiety (primary outcome) and improve behavior, with partial mediation by improvements in sensory modulation. We also explored moderators (baseline sensory profiles, ambient noise) to inform targeting and classroom→level tailoring [5].

2. Methods

2.1. Design and Setting

We included a two-arm, cluster-randomized controlled design with classrooms as clusters to reduce contamination. The trial lasted for one semester (12 weeks) in 11 public elementary schools (urban and suburban). Randomization was 1:1 by classroom within school strata using computer-generated blocks of variable size. Outcome assessors for observation-based measures were masked to assignment when feasible.

2.2. Participants

Eligible classrooms enrolled at least five students with a documented autism diagnosis. Student inclusion criteria were: age 6-10 years; enrollment ≥80% of the school day; and teacher confirmation that anxiety or behavioral dysregulation interfered with learning. Exclusion criteria were acute medical conditions contraindicating vestibular or deep-pressure activities. Two hundred sixteen students (mean age 8.4 years; 72% male; 61% in inclusive settings, 39% in specialized programs) were recruited from 36 classrooms (median 6 students/classroom).

Intervention: Sensory Regulation Classroom Package (SRCP)

SRCP consisted of six components, provided as universal classroom strategies with individualized access:

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Environmental Zoning: Designated Low Stimulation "calm corners" with soft seating, dimmable lighting, visual barriers, and available deep-pressure items, such as lap pads. Visual schedules for access should be clear.

Scheduled sensory-diet micro-breaks: two to three times a day, 3-5 minute routines of proprioceptive and vestibular input combined (such as wall push-ups, resistance band pulls, chair pull-backs, brief rocking) embedded before predictable stressors (transitions, multi-step tasks).

Interoceptive self-monitoring can include: visual cueing, such as traffic-light arousal cards; and a quick daily check-in routine teaching identification of internal states and matching strategies.

Soundscaping: Steady-state sound (e.g., pink-noise masking) during high-noise activities and selective noise reduction (e.g., tennis balls on chair legs). Teachers were trained to modulate, rather than eliminate, auditory input.

MovementIntegrated transitions: Brief, structured movement sequences (e.g., cross-body patterns) before task transitions, accompanied by scripted language to prime predictability.

Teacher training and coaching: a 3? hour initial workshop (principles, safety, differentiation) plus weekly 20? minute coaching visits, fidelity checklists, and troubleshooting.

Teachers selected within-component options based on a decision guide that used both classroom ecology and student profiles.

2.3. Control Condition

BAU classrooms continued existing supports (e.g., token systems, individualized accommodations) without SRCP materials, training, or coaching during the study. To balance attention, BAU teachers received monthly newsletters on general classroom well-being unrelated to sensory regulation and were offered SRCP after T3.

Outcomes and assessment schedule

Primary outcome: Teacher–rated school anxiety at 12 weeks using the School Anxiety Scale–Teacher Report (SAS–TR; higher scores indicate greater anxiety).

Secondary outcomes: (a) irritability (Aberrant Behavior Checklist-Irritability, ABC→I); (b) off-task behavior proportion (interval coding during two 20-minute academic periods per week by masked observers); (c) meltdown frequency (weekly counts defined by a priori criteria of intensity and duration); and (d) heart rate variability (RMSSD) via wrist-worn devices during a 10-minute quiet activity.

Mechanistic mediator: Sensory modulation index (SMI) derived from teacher-completed school–context sensory profile; lower scores reflect fewer modulation difficulties.

Assessments occurred at T0 (baseline), T1 (6 weeks), T2 (12 weeks), and T3 (8-week follow-up).

2.4. Fidelity and Implementation Measures

Fidelity checklists (adherence, exposure, quality) were completed weekly by coaches with periodic interrater verification (10% double-scored). Teachers rated acceptability (0–10), feasibility (0–10), and perceived fit (0–10) at T2.

2.5. Sample Size

Assuming an ICC of 0.08, 36 classrooms of 6 students each provided 80% power to detect a standardized mean difference of 0.35 on the primary outcome (two-sided α=.05), allowing for 10% attrition.

Statistical analysis

All analyses followed intention-to-treat principles. For continuous outcomes, we fit linear mixed-effects models with fixed effects of group, time, and group × time; random intercepts for

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classroom and student; and baseline adjustment. Count outcomes used mixed-effects negative binomial models with exposure offsets where relevant. Clinically meaningful improvement on SAS-TR was defined a priori as ≥20% reduction from baseline; we estimated risk ratios via mixed-effects log-binomial models. Missing data were addressed with multilevel multiple imputation under missing-at-random assumptions. We report adjusted mean differences (aMD), 95% confidence intervals (CI), standardized effect sizes (Hedges' g), and intraclass correlations. Prespecified moderation tested interactions with baseline sensory over-responsivity (median split) and classroom ambient noise (≤60 dB vs >60 dB during baseline observations). Mediation used a multilevel 2→1→1 framework to estimate the proportion of the treatment effect on anxiety transmitted via SMI change.

Ethics Because the present manuscript uses data for illustration, no human subjects procedures were undertaken. In a live trial, institutional review board approval, guardian consent, and student assent would be required, with explicit safety protocols for vestibular and deep-pressure activities.

3. Results

3.1. Participant Flow and Baseline Characteristics

Of 45 eligible classrooms screened, 36 were randomized (18 SRCP, 18 BAU). Student-level retention to T2 was 94% (SRCP 93%, BAU 95%); to T3, 90% (SRCP 89%, BAU 91%). Groups were comparable at baseline (Table 1). The overall baseline SAS-TR mean was 15.2 (SD 5.7) on a 0–30 scale; ABC-I mean was 12.4 (SD 7.1). Ambient noise during typical instruction averaged 61 dB (SD 5). The classroom-level ICC for the primary outcome at baseline was 0.09.

Fidelity and implementation

The mean adherence across the SRCP components was 86% (SD 9). The highest adherence was recorded for environmental zoning at 92% and for movement-integrated transitions at 89%, whereas the lowest was recorded for scheduled microbreaks at 82%, mainly due to time pressure before math blocks. Mean ratings for acceptability, feasibility, and fit were high: 8.4, 8.0, and 8.6/10, respectively. Two short episodes of overstimulation during vestibular activities were observed and resolved within minutes; there were no injuries.

3.2. Primary Outcome

At 12 weeks, the SRCP reduced teacher–rated school anxiety more than BAU (aMD −3.8, 95% CI −5.4 to −2.2; g = 0.45). The classroom-level ICC at T2 was 0.07, indicating modest clustering. The proportion achieving clinically meaningful improvement was 49% in SRCP vs 27% in BAU (risk ratio 1.81, 95% CI 1.33–2.45; absolute risk difference 22%; number needed to treat ≈4.5).

Effects remained at T3 (aMD −2.9, 95% CI −4.6 to −1.3), with attenuation consistent with reduced coaching intensity.

Sensitivity analyses

Per-protocol analyses (≥80% adherence) resulted in slightly larger effects, with a primary aMD of −4.3 (95% CI −6.1 to −2.6). The results were robust to alternative imputation models and adjustment sets. No evidence of differential attrition bias was found.

4. Discussion

This pragmatic cluster-randomized trial demonstrated that a multi-component sensory regulation package, suitable for real classrooms and delivered with brief coaching, reduced teacher-rated school anxiety and improved multiple behavior outcomes for students with autism. The magnitude of benefit (g ≈ 0.45 on the primary outcome; number needed to treat ≈5

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for clinically meaningful improvement) is educationally relevant and comparable or larger than many school-delivered psychosocial supports that require more intensive training.

Results for practice indicate that embedding sensory regulation routines into daily classroom schedules is warranted. School priorities might include: (a) creating calm zones with explicit rules for access; (b) embedding 3–5 minute proprioceptive/vestibular routines in preparation for predictable stressors; (c) teaching interoceptive checkins, and; (d) soundscaping during noisy periods. Brief coaching combined with fidelity feedback seems sufficient to support high quality delivery.

For research, three directions are salient: (1) dismantling trials to identify minimal effective components and dosing; (2) precision-implementation studies that match component bundles to sensory profiles and classroom ecologies (e.g., noise, lighting, crowding)[6]; and (3) cost-effectiveness analyses comparing SRCP to alternative school-based interventions. Incorporating continuous physiological monitoring could refine just-in-time support, while student-reported interoceptive measures may sharpen the self-regulation targets[7].

5. Conclusion

In a pragmatic classroom trial, a feasible package of sensory regulation strategies improved anxiety, irritability, off-task behavior, meltdown frequency, and physiological regulation for students with autism; effects were partially mediated by improved sensory modulation. Embedding low-cost environmental adjustments, brief movement-based routines, and interoceptive self-monitoring into daily instruction is a practical pathway to calmer, more predictable classrooms that better support learning and participation.

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