

Original article

Effects of Sensory Room Interventions on Vagal Function in Individuals with Depression: A Randomized Crossover Trial

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All participants were fully informed in advance, and written and verbal consent was obtained.

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The data supporting this study cannot be shared publicly because they contain sensitive information from individuals with mental health conditions and are subject to ethical and privacy restrictions imposed by the institutional review board.

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A Randomized Crossover Trial

Abstract

Background: Sensory rooms, widely used in psychiatric care, offer customizable environments designed to enhance comfort and reduce distress. Although our previous research demonstrated that sensory room use was associated with increased vagal activity in healthy individuals, its physiological effects in individuals with depression remain unclear.

Aim: This study aimed to examine the effects of a sensory room intervention on autonomic function and psychological outcomes in adults with depression.

Methods: Twenty adults with depression participated in a randomized crossover trial. Each participant completed two 30-minute sessions—sensory room use and static seated activities—in a counterbalanced order. Resting vagal activity, vagal reactivity to auditory stimulation, subjective discomfort, mood states, and interoceptive awareness were assessed before and after each session. Vagal indices were derived from respiratory sinus arrhythmia, a heart rate variability measure reflecting parasympathetic cardiac control. Mood was assessed with the Profile of Mood States, Second Edition, and interoceptive awareness with the Multidimensional Assessment of Interoceptive Awareness.

Results: Compared to static activities, the sensory room significantly increased resting vagal activity and reduced vagal reactivity to auditory stimuli, indicating enhanced autonomic stability. Although no significant differences were found in subjective discomfort or negative mood states, several aspects of interoceptive awareness, including the Not-Worrying subscale, showed significant improvement following sensory room use.

Conclusions: These findings suggest that sensory rooms may help regulate vagal function and support sensory modulation in individuals with depression, providing a non-pharmacological approach to enhance autonomic regulation and body awareness in psychiatric care.

Trial registration: UMIN-CTR (UMIN000051830), <https://www.umin.ac.jp/ctr/index.htm>

Keywords

Sensory Room; Depression; Vagal activity; Respiratory sinus arrhythmia; Randomized crossover trial

Introduction

Sensory rooms are therapeutic environments designed to provide adjustable visual, auditory, tactile, and olfactory stimuli tailored to individual preferences. In practice, they may consist of simple elements such as soft lighting, calming music, tactile materials that provide sensory input (e.g., weighted blankets or beanbag chairs), and aromatherapy oils, all intended to promote a sense of calm. While their design and use vary depending on the population and purpose, sensory rooms in psychiatric settings—often called sensory modulation rooms—are primarily intended to promote relaxation and emotional regulation (Champagne, 2017). These rooms are increasingly implemented in inpatient psychiatric care and are often facilitated by healthcare professionals. They have been associated with reduced anxiety, decreased use of physical restraints and medication, and improvements in overall well-being (Champagne, 2017; Forsberg et al., 2024; Haig & Hallett, 2023; Hedlund Lindberg et al., 2019). Despite these benefits, the mechanisms underlying their effects in individuals with depression remain poorly understood. Sensory rooms may alleviate depressive symptoms by promoting relaxation, reducing stress-related physiological arousal, and enhancing awareness of internal bodily states, all of which support emotional regulation.

A key physiological marker in this context is respiratory sinus arrhythmia (RSA), an index associated with stress responses and sensory modulation (Christensen et al., 2020). RSA is derived from high-frequency heart rate variability (HRV) (Taylor et al., 2022), and its

amplitude reflects the degree to which the vagus nerve, a branch of the parasympathetic nervous system, modulates heart rate (Lewis et al., 2012; Porges, 2007). Vagal function is commonly divided into two aspects: vagal tone, representing baseline vagal activity at rest, and vagal reactivity, indicating the degree of change in response to external stimuli (Porges, 2007; Weissman & Mendes, 2021). Individuals with sensory hypersensitivity tend to exhibit lower resting RSA and heightened RSA reactivity when exposed to sensory input (DeBoth et al., 2023; Otsuka, Irie, Takebuchi, et al., 2025; Schaaf et al., 2010). In addition, resting RSA and RSA reactivity to stress are linked to psychological states such as anxiety (Scott & Weems, 2014). Thus, RSA measured at rest and during sensory stimulation may serve as a useful indicator of sensory regulation and psychological state changes.

Depression is characterized by a marked reduction in high-frequency HRV, an index of vagal activity that is closely associated with impaired stress regulation (Schiweck et al., 2019). Individuals with depression also frequently exhibit difficulties in emotion regulation that interfere with daily functioning. To address these challenges, relaxation-based interventions—such as aromatherapy and mindfulness-based cognitive therapy—have been increasingly shown to be effective (Lam et al., 2024). Moreover, recent studies have reported diminished interoceptive awareness in depression, which refers to the conscious perception of internal bodily signals (Dunne et al., 2021). Both emotional regulation difficulties and reduced interoceptive awareness are closely tied to vagal tone and stress regulation (Schiweck et al.,

2019; Schultchen et al., 2019). Evaluating the effects of noninvasive, sensory-based interventions that target these physiological and perceptual dimensions may provide valuable insights into how sensory rooms alleviate depressive symptoms. Such interventions may also enhance emotional regulation and interoceptive awareness, thereby supporting clinical intervention planning for individuals with depression.

In a previous pilot randomized controlled trial with healthy adults, we found that sensory room intervention (SRI) significantly increased RSA compared to sedentary activity (SA), and that SRI reduced RSA variability in response to auditory stimuli (Otsuka, Irie, Kogata, et al., 2025). However, despite the growing use of sensory rooms in psychiatric settings, little is known about their physiological impact on individuals with depression. This lack of empirical evidence limits mental health care staff's ability to fully implement evidence-based sensory interventions in psychiatric care. Examining both the autonomic and psychological effects of sensory room interventions may strengthen clinical reasoning and support more effective intervention planning.

To investigate these aspects, we conducted a randomized crossover trial to investigate the effects of SRI on vagal function in individuals with depression. The primary outcomes were indices of vagal function, namely resting vagal tone and vagal reactivity to auditory stimulation, assessed using RSA. The secondary outcomes included subjective discomfort, mood states, and interoceptive awareness.

We hypothesized that, compared to static activities, the SRI would (1) increase resting vagal tone, (2) reduce vagal reactivity to auditory stimulation, (3) decrease subjective discomfort in response to auditory stimuli, (4) decrease negative mood states, and (5) improve interoceptive awareness.

Materials and Methods

Study Design

This study was designed as a two-arm randomized crossover trial in which participants underwent both SRI and SA in a counterbalanced order.

Participants

Participants were individuals with depression living in a local area, recruited through the website of 3H Medisolution Co., Ltd (Tokyo, Japan). The inclusion criteria were as follows: age 18 to 65 years at the time of enrollment, diagnosis of depressive disorder, no planned changes in primary medication during the intervention period, and a total score of 1 or higher on the Japanese Sensory Inventory mini score (Ota, 2004). The exclusion criteria were the presence of comorbid cardiovascular disease; use of a cardiac pacemaker; history of epilepsy; abnormalities in vision, hearing, touch, smell, or taste; resistance to or fear of enclosed spaces; risk of self-harm or harm to others; inability to complete the study due to anticipated hospitalization or transfer; and any history of visual or auditory impairment, language comprehension issues, or motor dysfunction that could affect the study. All participants were

included in the final analysis.

Using G*Power 3.1.9.2 and referencing the results of our previous study on resting and stimulus-induced RSA variability (Otsuka, Irie, Kogata, et al., 2025), we estimated the required sample size using effect sizes of 0.61 and 0.45, with an α error of 0.05 and a β error of 0.20. The calculations indicated that a sample size of 8 or 12 participants was needed. In the present study, 20 individuals participated, and a post hoc power analysis confirmed a statistical power of 1.0, indicating that the sample size was sufficient. This study received approval from the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (Approval No. C1636-1), and written informed consent was obtained from all participants.

Interventions

For both the SRI and SA procedures, all assessments and interventions were administered in a private, quiet room measuring approximately $3 \times 3 \text{ m}^2$. The intervention time for both conditions lasted 30 minutes. A single licensed occupational therapist (the first author) served as the tester and remained seated quietly at a desk in the corner of the room during the interventions, monitoring participants' safety and overall engagement. The tester did not engage in any communication, including conversation, while recording participants' activities. One participant had comorbid social anxiety disorder; therefore, a companion was present in the room during all interventions and assessments to minimize potential psychological discomfort associated with being alone. However, there was no verbal communication between

the companion and the participant during the interventions.

Sensory Room Intervention (SRI)

The SRI was based on previous studies (Björkdahl et al., 2016; Doroud et al., 2024; Hedlund Lindberg et al., 2019) and our prior research (Otsuka, Irie, Kogata, et al., 2025). Various sensory items, such as a beaded cushion, weighted blanket, rocking chair, bubble tube, aroma oils, and healing music, were prepared to facilitate a calming environment. Details on the specific items are available in our previous studies (Otsuka, Irie, Kogata, et al., 2025). Before each 30-minute intervention, the tester explained how to use each item and allowed participants to briefly try them. Participants were then instructed: “Please create a relaxing environment using any of the items you feel would help you relax.” After participants completed their setup, the 30-minute SRI began. The intervention began in a dimly lit room with the bubble tube, aroma diffuser, and healing music turned on, and participants could turn them off at any time. During the session, they could also change or adjust any other sensory items as needed. Prior to the intervention, participants were reminded to stay awake throughout the session. An example of how to spend time in a sensory room is shown in Figure 1.

Sedentary Activity (SA)

The SA intervention was designed based on conventional psychiatric occupational therapy and our previous study (Otsuka, Irie, Kogata, et al., 2025), with all activities requiring fewer than three metabolic equivalents. The participants freely chose activities such as puzzle-

solving, reading, coloring, and origami, as described in our previous study (Otsuka, Irie, Kogata, et al., 2025). The intervention occurred in a well-lit room while participants remained seated and were free to change their activities at any time. The SA condition did not use the same items as the SRI, and the activities were designed to exclude tools focused on sensory input. The participants' activities during the SA and SRI interventions are presented in Supplemental Tables 1 and 2.

Measures

In both conditions, we assessed several outcomes before and after the intervention: resting RSA, RSA changes from rest to discomforting auditory stimulus, scores from the Profile of Mood States Second Edition (POMS2) (Heuchert & McNair, 2012), and the Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012). POMS2 and MAIA, as secondary outcomes, were evaluated before and after the RSA measurements.

Measurement of RSA During Auditory Stimulation

We used the prolonged auditory stimulus in the sensory challenge protocol (DeBoth et al., 2023; Miller et al., 1999; Schaaf et al., 2010). The task began with a rest period (3 minutes), followed by a prolonged auditory stimulus (75 dB, 2 minutes), and a recovery period (3 minutes). Before the stimulus began, the participants were informed about the auditory stimulus and asked to look at the fixation point on the display. We measured participants'

subjective discomfort to assess the emotional changes caused by the auditory stimulus. They rated their discomfort in response to the auditory stimulus on an 11-point Likert scale, ranging from 0 (not unpleasant at all) to 10 (extremely unpleasant).

RSA Calculation

RSA was derived from photoplethysmographic signals obtained using a portable pulse wave device (Polypul II; Nihonsanteku, Osaka, Japan) with a sampling rate of 1000 Hz. Data preprocessing and RSA quantification were conducted using CardioEdit and CardioBatch software (Brain-Body Centre, University of Illinois, Chicago, USA), which implement the Porges–Bohrer method (Lewis et al., 2012; Porges, 2007; Porges & Bohrer, 1990). In this procedure, artifacts were visually identified and corrected, a moving polynomial filter was applied to remove nonstationary components, and RSA was estimated in 30-s epochs. It reflects heart rate variability in the high-frequency range associated with spontaneous respiration (approximately 0.25–0.33 Hz, i.e., a cycle of about three to four seconds). The variance of each epoch was then log-transformed ($\ln[\text{ms}^2]$) and averaged to obtain RSA values. Details of the signal processing and RSA calculation procedures are described in our previous publication (Otsuka, Irie, Takebuchi, et al., 2025). RSA values were calculated for the initial resting state, the auditory stimulation, and the final recovery period.

Assessment of Mood State

The short Japanese version for adults (35 items) of the POMS2 was used to assess

participants' current mood. This standardized, self-administered questionnaire evaluates various mood states (Heuchert & McNair, 2012; Yokoyama, 2015). The POMS2 assesses six mood subscales: Anger/Hostility, Confusion/Bewilderment, Depression/Dejection, Fatigue/Inertia, Tension/Anxiety, and Vigor/Activity. The total mood disturbance (TMD) score was calculated as a T-score, with higher values reflecting a more negative mood state. Previous research has demonstrated good internal consistency and construct validity of the POMS2 (Heuchert & McNair, 2012). Psychometric properties of the Japanese short version, including reliability and validity, have also been reported in the Japanese manual (Yokoyama, 2015).

Assessment of Interoceptive Awareness

The Japanese version of the MAIA (Mehling et al., 2012; Shoji et al., 2018) was used in this study. It is a self-report questionnaire designed to assess multiple dimensions of interoceptive body awareness. It consists of 32 items grouped into eight subscales: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. Participants respond using a 6-point Likert scale ranging from 0 ("never") to 5 ("always"). Higher scores indicate greater interoceptive awareness, reflecting a stronger tendency to recognize and utilize internal bodily sensations positively and adaptively. The MAIA has demonstrated good reliability and validity (Mehling et al., 2012; Shoji et al., 2018).

Procedure

Conducted and reported in accordance with the CONSORT 2010 guidelines, the corresponding checklist is included in the Supplemental File 1. It was registered as a clinical trial with the UMIN Clinical Trials Registry (UMIN-CTR; ID: UMIN000051830), with the full title of the registered protocol: Evaluation of the Effects of an Intervention Using the Sensory Room on Sensory Processing Characteristics in Adults with Psychiatric Disorders: A Randomized Crossover Trial.

We employed a block randomization method with stratification by sex to assign participants. A sequence for random assignment was produced with the RAND function in Microsoft Excel. The enrollment period was from October 7, 2024 to March 3, 2025, and the follow-up period lasted until March 11, 2025. One author (H.O.) generated the random assignment sequence, enrolled participants, and allocated them to the intervention conditions described above. Another author (K.I.) quantified the RSA, including visual noise processing, under blinded conditions.

Figure 2 illustrates the flowchart of the study protocol. All participants were screened for eligibility based on their demographic information and responses to the Japanese Sensory Inventory mini (Ota, 2004), which was used as part of the inclusion criteria. Before the intervention and outcome assessments, participants reported their diagnosis and medical history (including the timing of their initial consultation and any history of hospitalization), as well as their employment history. To characterize the sample, participants completed the

Japanese version of the Quick Inventory of Depressive Symptomatology–Self Report (QIDS-J) (Rush et al., 2003), the Autism Spectrum Quotient (Baron-Cohen et al., 2001), the Adolescent/Adult Sensory Profile (Brown & Dunn, 2002), and the FLANDERS Handedness Questionnaire (Nicholls et al., 2013). We conducted several assessments before and after the intervention, as described above. Group assignments were disclosed to participants following the completion of the pre-intervention assessment in the first experiment. A washout period of at least one week (15.00 ± 8.09 days) was implemented between the two interventions for all participants except for one, who had a 6-day interval due to their scheduling constraints. Since cardiovascular function is influenced by circadian rhythms (Lecacheur et al., 2024), assessments and interventions were conducted at the same time of day for each participant whenever possible.

Statistical Analysis

After confirming data normality using the Shapiro–Wilk test, repeated-measures analyses of variance were conducted to examine the effects of the intervention condition (SRI vs. SA) and time point (pre- vs. post-intervention) on various outcomes. These included resting RSA, RSA changes during auditory stimulation (calculated as the difference from the initial resting state), and subjective discomfort levels during auditory stimulation. The Greenhouse–Geisser correction was applied when sphericity assumptions were violated, and effect sizes were calculated to assess practical significance. The significance level was set at $p < .05$.

In addition, for POMS2 and MAIA, Wilcoxon signed-rank tests with Bonferroni correction were conducted on subscale change scores (post–pre) to compare the two intervention conditions. For these tests, the significance level was set at $p < .0063$. All analyses were performed using IBM SPSS Statistics, version 26.

Results

Demographic data are displayed in Table 1. Overall, 20 individuals with depression participated (7 men, 13 women; mean age = 39.7 years [SD = 10.8]). On average, participants had 15.4 years of education (SD = 2.1); 50% were employed, and 45% were unemployed. The mean age at first depressive episode was 30.6 years (SD = 9.4), with an average illness duration of 9.1 years (SD = 6.3). Common comorbidities included attention-deficit/hyperactivity disorder (25%), autism spectrum disorder (15%), and anxiety disorders (15%). The mean QIDS-J score was 12.2 (SD = 5.3), and the average imipramine-equivalent dose was 77.6 mg/day (SD = 65.6). All participants were receiving psychotropic medication at the time of the study.

Effect on RSA

Regarding resting RSA, significant main effects were found for both intervention condition ($F[1, 19] = 5.28, p = .033, \eta^2 = .22$) and time ($F[1, 19] = 21.35, p < .001, \eta^2 = .53$). Importantly, a significant interaction between intervention condition and time was also observed ($F[1, 19] = 16.92, p = .001, \eta^2 = .47$), indicating that resting RSA increased more

after the SRI (Figure 3).

For RSA changes from rest to auditory stimulation, a marginally non-significant main effect of intervention condition was observed ($F[1, 19] = 4.40, p = .050, \eta^2 = .19$), along with a significant main effect of time ($F(1, 19) = 14.72, p = .001, \eta^2 = .44$). A significant interaction between intervention condition and time was also found ($F[1, 19] = 4.55, p = .046, \eta^2 = .19$), indicating that the decrease in RSA from rest to auditory stimulation was greater after the SRI (Figure 4). Supplemental Table 3 presents the pre- and post-intervention means ($\pm$ standard error) of resting RSA and RSA changes from rest to auditory stimulation.

Subjective Discomfort Levels

Regarding the subjective discomfort levels in response to the auditory stimulus, a significant main effect of time was observed ($F[1, 19] = 15.26, p = .001, \eta^2 = .45$), with lower mean scores observed post-intervention compared to pre-intervention, indicating a reduction in perceived discomfort. However, no significant main effect of intervention condition was found ($F[1, 19] = 2.80, p = .11, \eta^2 = .13$), and no significant interaction between time and intervention condition was observed ($F[1, 19] = .00, p = 1.00, \eta^2 = .00$). Comparisons of pre- and post-intervention scores on the subjective discomfort levels by intervention condition are presented in Supplemental Table 4.

Effect on Mood States and Interoceptive Awareness

Table 2 shows no statistically significant differences between the two intervention conditions for the POMS2 scores. However, comparisons of pre- and post-intervention scores within each condition, presented in Supplemental Table 5, indicated that both the SA and SRI interventions were associated with reductions in negative mood states, including Anger/Hostility, Depression/Dejection, Fatigue/Inertia, and Tension/Anxiety.

Regarding the MAIA, as shown in Table 3, the Not-Worrying subscale score significantly increased following the SRI compared to the SA condition ($p = .004$, $r = -.65$). Although the other subscales did not reach statistical significance, there were trends toward improvement for the Self-Regulation ($p = .013$, $r = -.56$) and Trusting ($p = .036$, $r = -.47$) subscales. Detailed comparisons of pre- and post-intervention MAIA scores by condition are provided in Supplemental Table 6.

Discussion

This study investigated the effects of an SRI on vagal function, subjective discomfort to auditory stimuli, mood state, and interoceptive awareness in individuals with depression. The results demonstrated that SRI significantly increased resting RSA, suggesting enhanced vagal tone compared to the SA. Furthermore, SRI was associated with smaller changes in RSA from rest to auditory stimulation, indicating reduced vagal reactivity. No significant differences were found between the two conditions in terms of subjective discomfort to auditory stimuli or negative mood states as measured by the POMS2. However, for several subscales of

interoceptive awareness measured by the MAIA, the SRI condition showed significant or non-significant trend-level improvements compared to the SA. The findings provide insight into the role of sensory rooms in sensory modulation and autonomic regulation, as well as suggestions for relaxation methods for individuals with depression.

Vagal Tone and Vagal Reactivity Change

Our results align with prior findings in studies involving healthy adults (Otsuka, Irie, Kogata, et al., 2025) and our hypothesis, suggesting that sensory room interventions can modulate autonomic activity, given that RSA (i.e., vagal tone) is closely linked to psychological states such as anxiety (Scott & Weems, 2014). The observed increase in RSA following the intervention likely reflects a calming physiological response. This interpretation is consistent with earlier reports that sensory environments can promote relaxation and reduce distress (Doroud et al., 2024; Haig & Hallett, 2023; Hedlund Lindberg et al., 2019). Furthermore, individual components of the sensory room—such as soothing music (Iwanaga et al., 2005), weighted blanket (Becklund et al., 2021), and aromatic stimuli (Yang et al., 2015)—have each been shown to enhance parasympathetic nervous system activity or decrease pulse rate. These multimodal stimuli may have collectively contributed to the increased vagal tone observed in this study.

Since our participants were individuals with depression, it should be noted that this population often exhibits reduced baseline vagal activity (Udupa et al., 2007). Low baseline

vagal tone has been reported to be associated with the severity of major depressive disorder (Yeh et al., 2016). Furthermore, reduced vagal tone in depression has been linked to difficulties in emotion regulation and impaired mood repair (Yaroslavsky et al., 2016). Conversely, an increase in vagal tone or HRV following intervention has been identified as a marker of favorable treatment response in major depression, and improving HRV has been shown to reduce depressive symptoms (Chambers & Allen, 2002; Pizzoli et al., 2021). Therefore, the increase in vagal tone observed following the SRI intervention in this study may contribute to symptom improvement in patients with depression, highlighting the need for further research that also considers psychological outcomes.

In response to auditory stimulation, RSA decreased more markedly after the SRI intervention than after the SA intervention, indicating a more attenuated vagal response to sensory input. This finding generally supports our previous study (Otsuka, Irie, Kogata, et al., 2025) and our hypothesis.

The reduced vagal reactivity following SRI may reflect an increased tolerance to sensory stimulation. Typically, increased vagal activity during stress indicates self-regulation efforts or recovery from a stressful state (Balzarotti et al., 2017). Therefore, the reduced change in RSA from rest to auditory stimulation after SRI may suggest a decreased need for regulation or recovery, reflecting diminished sensitivity to sensory input. This implies that sensory room interventions may influence aspects of sensory regulation mediated by the autonomic nervous

system (Lane et al., 2019). However, further research is required to confirm this effect.

Moreover, vagal reactivity to sensory stimuli is associated with difficulties in sensory regulation. Individuals with atypical sensory modulation often show heightened vagal responses to sensory input (DeBoth et al., 2023; Otsuka, Irie, Takebuchi, et al., 2025; Schaaf et al., 2010), and many people with psychiatric conditions exhibit atypical sensory regulation (Bailliard & Whigham, 2017; Van Den Boogert et al., 2022). These findings suggest that SRI benefits individuals with psychiatric disorders or with sensory regulation difficulties by supporting more adaptive autonomic responses to sensory stimuli.

Subjective Discomfort Levels Changes

In both the SA and SRI groups, subjective unpleasantness in response to auditory stimuli decreased after the intervention, with no significant differences or interactions observed between the intervention conditions. These results did not align with the initial hypothesis or demonstrate a specific effect of the sensory room intervention.

The post-intervention reduction in unpleasantness observed in both groups may reflect habituation due to repeated exposure to sensory stimuli. Repeated sensory stimulation reduces reactivity in emotion-processing networks, such as the amygdala (Green et al., 2019), and the present findings may be consistent with this neurophysiological mechanism.

Conversely, the RSA responses to auditory stimuli did not mirror the changes in subjective unpleasantness, suggesting that autonomic reactivity and subjective sensory

experiences may not always align. This discrepancy may occur because RSA reflects unconscious physiological responses that are independent of conscious cognition (Thayer & Lane, 2000), implying that the effects of SRI may be more sensitively detected through physiological indices like RSA than through self-reported measures.

Mood State Changes

Within-condition analyses showed pre–post reductions in several POMS2 domains for both SRI and SA. However, no statistically significant differences were found between the two conditions, and our hypothesis was not supported. Therefore, the present data do not allow for conclusions regarding the superiority or effectiveness of either intervention for mood regulation.

Previous studies have reported that creative activities contribute to mood improvement and well-being (Burns & Van Der Meer, 2021) and that sensory rooms may promote feelings of safety and improved emotional regulation (Doroud et al., 2024; Haig & Hallett, 2023). In addition, multisensory interventions using music and vibration have also been shown to alleviate depressive symptoms and anhedonia (Braun Janzen et al., 2019). In contrast to those findings, the present study did not demonstrate significant mood improvements attributable specifically to SRI.

Psychological states typically associated with SRI—such as “comfort” and “a sense of safety”—may not be adequately captured by the POMS2, which focuses primarily on negative

mood states. Future studies should consider incorporating more multifaceted psychological measures.

Interoceptive Awareness Changes

In the present study, the MAIA "Not-Worrying" subscale showed a significant increase in the SRI condition compared to the SA condition. Furthermore, although not statistically significant, the "Self-Regulation" and "Trusting" subscales also demonstrated trends toward improvement in the SRI condition. These results partially supported our hypotheses. These changes suggest a reduction in excessive worry regarding unpleasant bodily sensations, an enhanced ability to regulate discomfort, and an increased sense of trust in bodily signals (Mehling et al., 2012). Thus, the sensory input provided by the SRI may have helped to attenuate negative evaluations and concerns related to interoceptive experiences.

These subscales are conceptually related to emotion regulation; however, the POMS2 scores did not show significant differences or a trend between the two conditions. This discrepancy suggests that the SRI exerts its effects not directly on emotional states themselves, but rather by modifying awareness and evaluation of bodily sensations associated with those emotional states. Shifts in attention toward interoceptive signals are associated with improved emotion regulation and reduced anxiety (Price & Hooven, 2018; Sugawara et al., 2020). Although the SRI primarily provided exteroceptive inputs—such as visual, auditory, and olfactory stimuli—the gentle sensory environment of the sensory room may have, through as

yet unclear neural mechanisms, facilitated increased attention toward interoceptive signals, thereby fostering emotional regulation and a more accepting, non-worrying attitude toward bodily sensations.

Moreover, relaxation states enhance interoceptive accuracy (Fairclough & Goodwin, 2007), and greater HRV, reflecting enhanced parasympathetic activity, is associated with improved interoceptive detection (Lischke et al., 2021). Given that RSA (an index of parasympathetic activity) increased following the SRI intervention in the present study, it is plausible that participants' interoceptive awareness was also heightened post-intervention. Farb et al. (2013) demonstrated using functional magnetic resonance imaging that the insular cortex serves as an integration hub for exteroceptive and interoceptive input, highlighting a potential neural basis by which external sensory stimulation may modulate internal bodily awareness. These findings suggest that future research should incorporate objective measures of interoceptive accuracy, such as heartbeat perception tasks, and neuroimaging-based assessments of interoceptive brain regions to more comprehensively investigate the mechanisms through which SRI influences interoceptive awareness.

In addition, it is important to note that diminished interoceptive awareness has been reported as a characteristic feature of depression. Reduced interoceptive awareness is associated with greater depressive symptom severity (Dunne et al., 2021), and studies have shown a progressive decline in interoceptive functioning across stages of depression (Zhou et

al., 2024). Therefore, the improvement observed in the MAIA “Not-Worrying” subscale may reflect clinically meaningful changes in interoceptive processes among individuals with depression. Future studies are needed to examine whether such changes contribute to improvements in depressive symptoms and emotion regulation capacity.

Safety and Adverse Events

No adverse events were observed in this sample. Nevertheless, previous reports have indicated potential negative effects of sensory room use in clinical populations. For example, Björkdahl et al. (2016) reported that sensory room use in certain psychiatric settings may induce or exacerbate symptoms such as auditory hallucinations, self-injurious behavior, panic attacks, claustrophobia, and heightened anxiety. For individuals experiencing depressive symptoms, being alone in a quiet space may contribute to a sense of social isolation, which could potentially worsen mood states. Furthermore, for individuals with sensory hypersensitivities, intense or poorly tailored stimuli—such as bright lights, strong scents, or specific sounds—may be experienced as unpleasant or overwhelming (Brown & Dunn, 2002). These findings underscore the need for individualized assessment and careful monitoring when implementing sensory-based interventions for individuals with complex mental health conditions.

Limitations

This study had some limitations. First, the diagnosis of depression was based on self-

report rather than standardized clinical criteria. Moreover, approximately 75% of participants had comorbid conditions, making it difficult to isolate the effects of the intervention on depression alone. In particular, neurodevelopmental conditions such as autism spectrum disorder and attention-deficit/hyperactivity disorder may influence how sensory stimuli are perceived and processed. Such differences may contribute to variability in responses to sensory-based interventions, as sensory processing difficulties have been reported transdiagnostically across psychiatric disorders (Van Den Boogert et al., 2022). Although the crossover design minimized between-subject variability and ensured no changes to primary medications during the intervention, HRV may still be influenced by antidepressants such as selective serotonin reuptake inhibitors (Fiani et al., 2023), warranting caution in interpretation. Additionally, all participants were receiving psychotropic medication at the time of the study, and information regarding the duration of pharmacological treatment was not available. Therefore, the generalizability of the present findings to unmedicated individuals or those in the early stages of pharmacological treatment remains limited.

Second, activities during both the SA and SRI conditions were selected by the participants. In addition, the SA condition included some degree of sensory input, meaning sensory stimulation was not fully controlled. For more rigorous evaluation of SRI effects, future studies should employ standardized activity protocols or conduct statistical analyses that account for individual differences, potentially by increasing the sample size.

Finally, the evaluation measures also had limitations. The POMS2 and MAIA assessments were conducted after pulse wave measurement, which may have attenuated intervention effects. In addition, the auditory unpleasantness ratings, POMS2, and MAIA were based on self-report, potentially affecting the reliability and validity of the findings.

Relevance for clinical practice

Depression is frequently accompanied by autonomic dysregulation, particularly reduced parasympathetic activity, which is linked to difficulties in stress regulation and emotional well-being (Schiweck et al., 2019). SRIs provide a non-pharmacological, client-centered approach to supporting autonomic regulation and promoting emotional stability in individuals with depression. Furthermore, sensory processing difficulties—such as hypersensitivity—are commonly observed in individuals with depression and other mental health conditions (Van Den Boogert et al., 2022). By offering a structured and calming environment tailored to individual sensory needs, SRIs may facilitate sensory comfort and physiological regulation, suggesting their potential value as a complementary approach in mental health care.

In clinical practice, sensory rooms have been introduced in psychiatric settings both as alternatives to seclusion and restraint and as ward-based spaces that patients can access at their preferred times (Doroud et al., 2024; Haig & Hallett, 2023). In addition to dedicated sensory rooms, incorporating selected sensory stimulus items (e.g., calming visual, tactile, or auditory

stimuli) into existing clinical environments may represent a feasible and scalable approach to supporting sensory and autonomic regulation. Furthermore, SRIs may also contribute to the development of self-regulation spaces within patients' homes, thereby extending their potential benefits beyond inpatient treatment.

Given the central role of nurses in the implementation of non-pharmacological interventions in psychiatric care, these findings have potential implications for psychiatric nursing practice. For generalist psychiatric nurses, sensory-based interventions may serve as practical, non-pharmacological strategies that may support autonomic regulation and interoceptive awareness in patients with depression. Nurses may play an important role in assessing individual sensory preferences, facilitating access to sensory resources, monitoring patient responses, and ensuring safety during implementation. For advanced practice psychiatric nurses, the findings may inform the development of individualized sensory-based care plans, staff education, and the integration of sensory interventions into broader therapeutic programs.

However, the present study does not allow us to determine whether the observed effects were attributable to the overall sensory environment or to specific sensory stimuli within the room. Further research is therefore required to identify the most critical elements and to establish evidence-based implementation strategies.

Conclusion

This study examined the effects of a sensory room on resting vagal tone and vagal reactivity to auditory stimulation in individuals with depression. Additionally, we investigated its impact on subjective mood states and interoceptive awareness. The results demonstrated that the sensory room intervention enhanced vagal function compared to a static seated activity. Furthermore, the sensory room improved several aspects of interoceptive awareness. These findings suggest that sensory rooms may facilitate the regulation of vagal activity and sensory processing in individuals with depression. Future research should further clarify the psychophysiological mechanisms through which sensory room interventions influence autonomic and interoceptive processes and determine how these mechanisms generalize across different clinical populations.

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Figure Legends

Figure 1

Example of sensory room use

Figure 2

Experimental procedure flow diagram

Note. MAIA = Multidimensional Assessment of Interoceptive Awareness; POMS2 = Profile of Mood States 2nd Edition; RSA = Respiratory sinus arrhythmia.

Figure 3

Changes in resting respiratory sinus arrhythmia before and after the intervention

Note. Light grey (Sedentary Activity) and orange circles (Sensory Room) indicate individual data points; circles outlined in black represent the mean; error bars indicate standard errors.

Figure 4

Changes in respiratory sinus arrhythmia (RSA) from baseline to auditory stimulation before and after the intervention

Note. The y-axis represents the difference between RSA during auditory stimulation and baseline (auditory minus baseline). Positive values indicate an increase in RSA during auditory stimulation compared to baseline. Light grey (sedentary activity) and orange circles (sensory room) indicate individual data points; circles outlined in black represent the mean; error bars indicate standard errors.

Figure 1



Figure 2

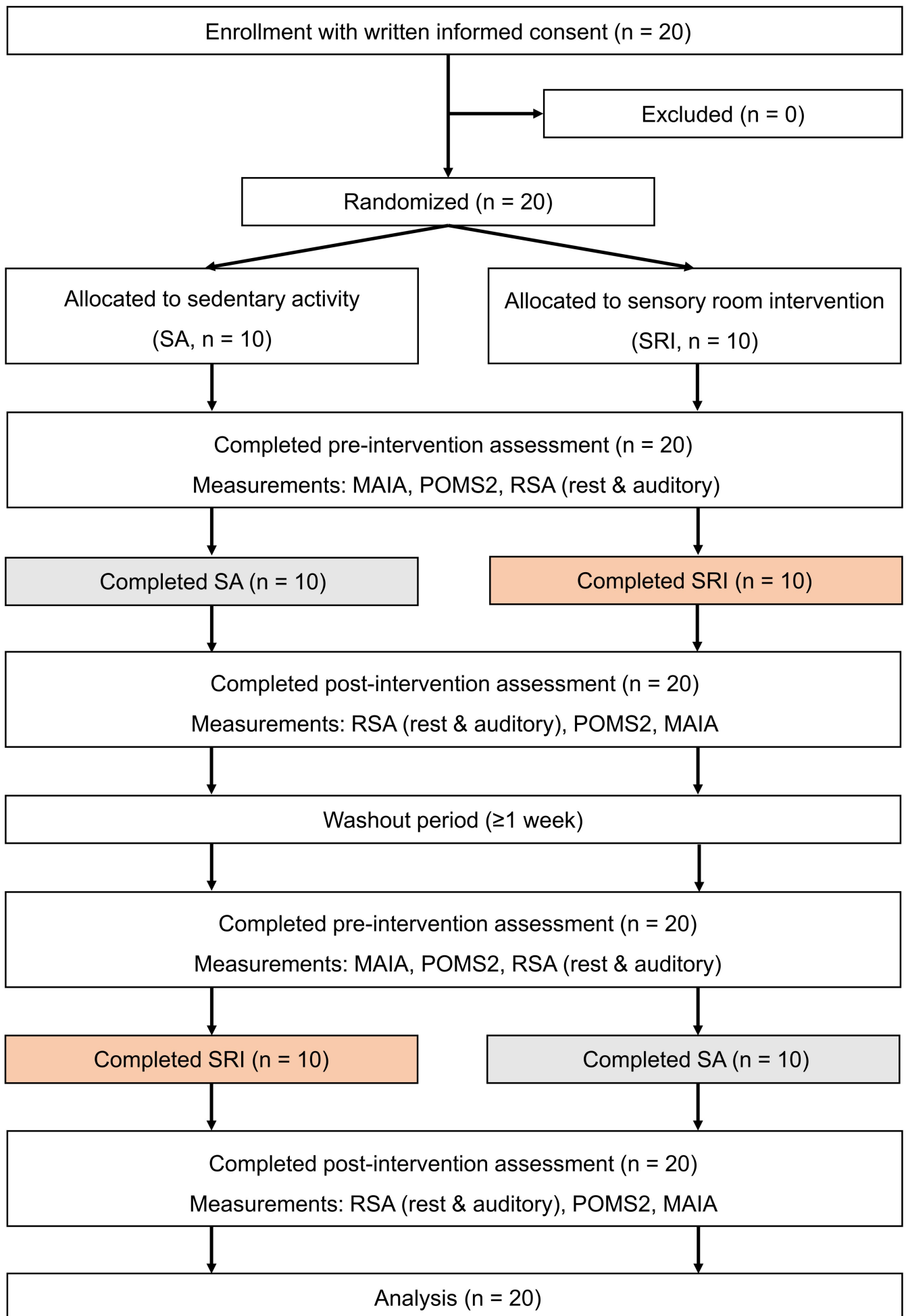


Figure 3

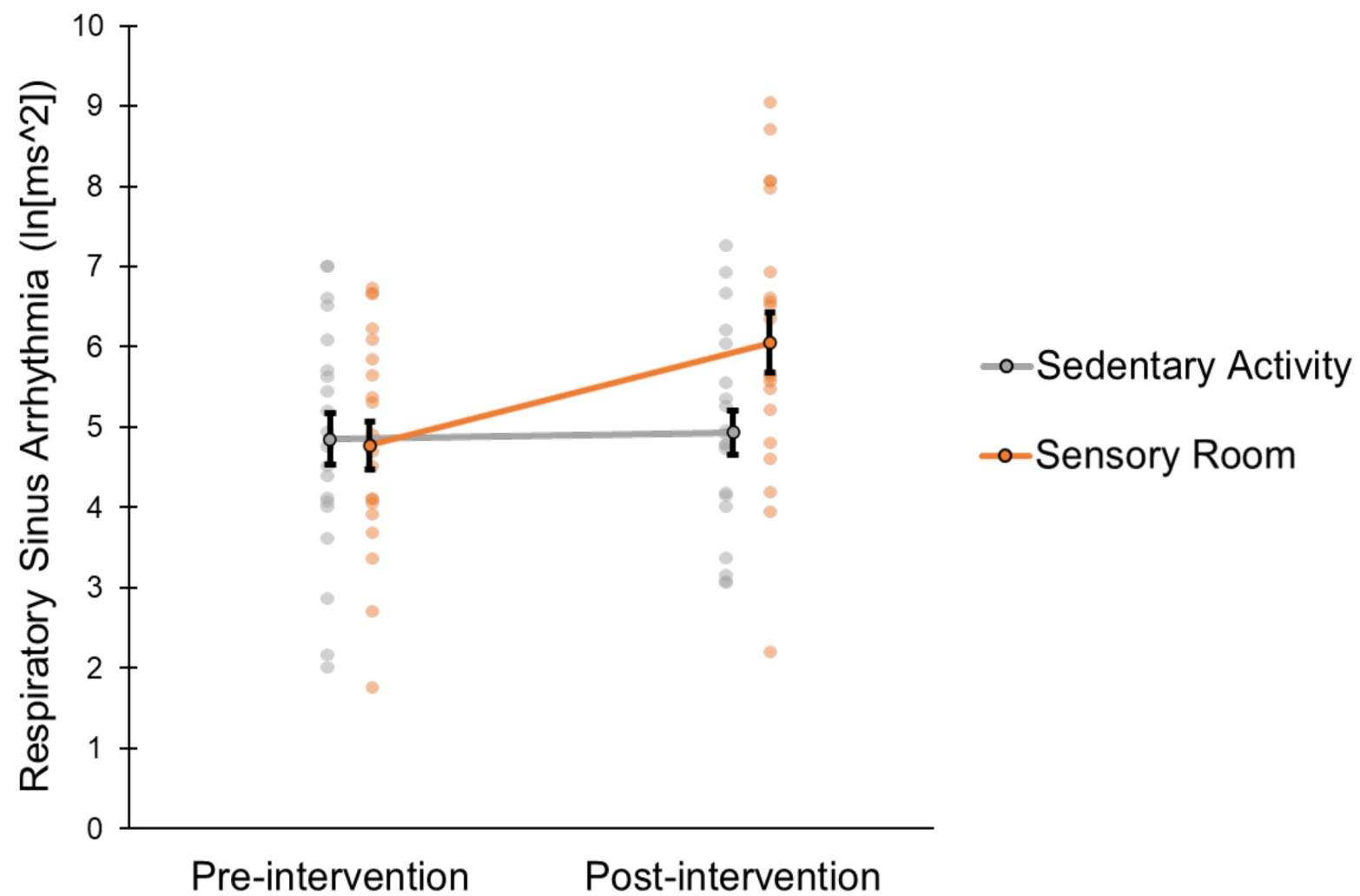
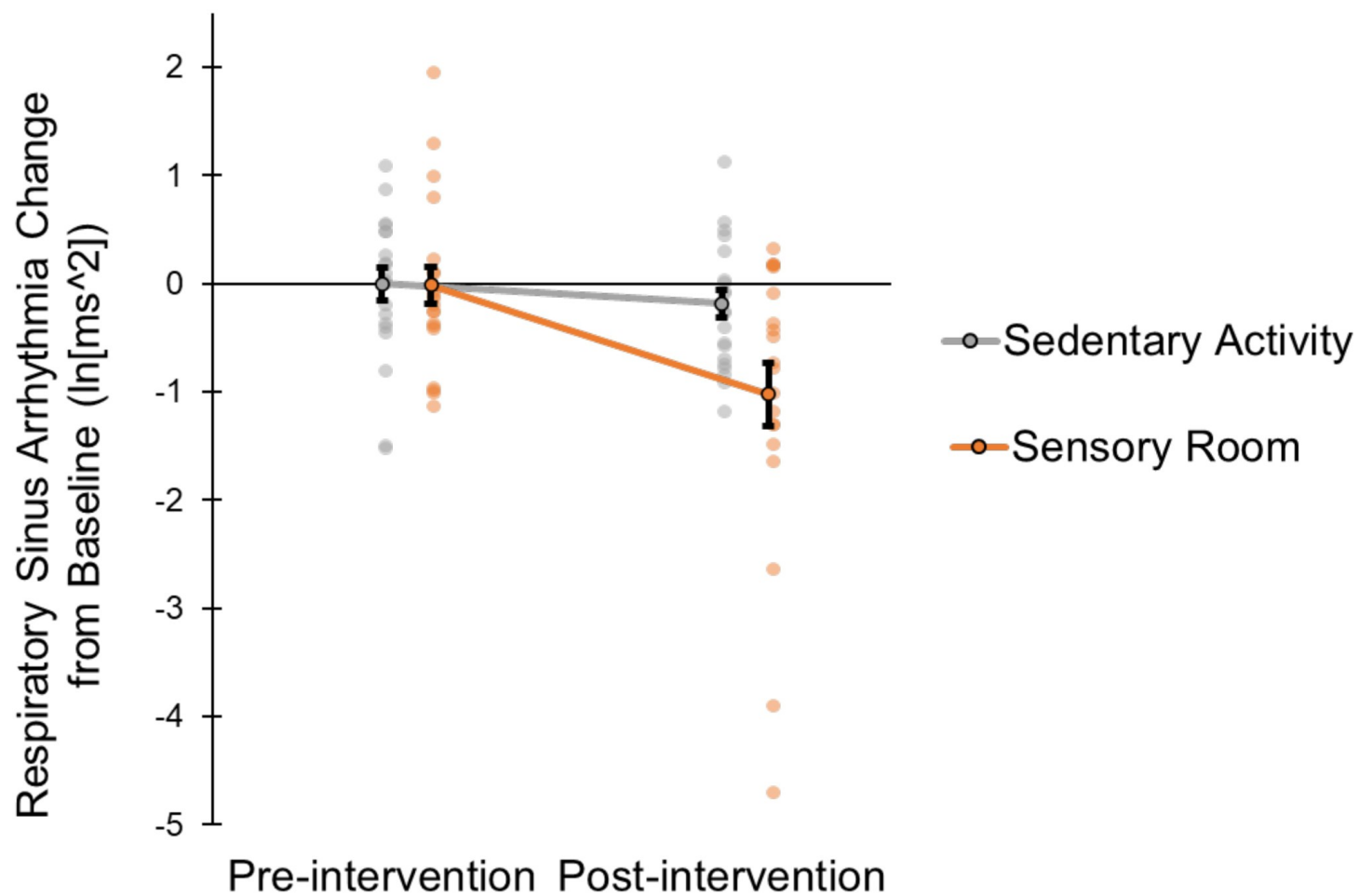


Figure 4



Tables

Table 1

Demographic data.

Characteristics	Mean (<i>SD</i>) or <i>n</i> (%)
Sex, <i>n</i> (%)	
Male	7 (35.0)
Female	13 (65.0)
Age (years)	39.7 (10.8)
Educational level (years)	15.4 (2.1)
Employment status, <i>n</i> (%)	
Unemployed ^a	9 (45.0)
Employed	10 (50.0)
Student	1 (5.0)
Age at onset of first depressive episode (years)	30.6 (9.4)
Years since first psychiatric visit (years)	9.1 (6.3)
Comorbidities, <i>n</i> (%)	
Depression only	5 (25.0)
Attention-deficit / hyperactivity disorder	5 (25.0)
Autism spectrum disorder	3 (15.0)
Anxiety disorders	3 (15.0)
Adjustment disorder	2 (10.0)
Bipolar disorder	2 (10.0)
Panic disorder	2 (10.0)
Premenstrual dysphoric disorder	1 (5.0)
Learning disorder	1 (5.0)
Sex dysphoria	1 (5.0)
Somatic conditions ^b	6 (30.0)
QIDS-J ^c total score	12.2 (5.3)
Currently receiving psychotropic medication, <i>n</i> (%)	20 (100.0)
Imipramine-equivalent dose (mg/day)	77.6 (65.6)
Autism spectrum quotient (AQ)	25.2 (7.0)
Adolescent/adult sensory profile (AASP)	
Low registration	33.3 (6.8)
Sensation seeking	34.3 (7.5)
Sensory sensitivity	43.6 (8.8)

Characteristics	Mean (<i>SD</i>) or <i>n</i> (%)
Sensation avoiding	43.4 (9.4)

Note. *N* = 20. SD = standard deviation. ^a Unemployed includes housewives and job seekers. ^b

Somatic conditions include hypertension, asthma, fibromyalgia, atopic dermatitis, and spinal

disc herniation. ^c QIDS-J = Japanese version of the Quick Inventory of Depressive

Symptomatology-Self Report.

Table 2

Changes in Profile of Mood States 2nd Edition (POMS2) scores.

POMS2 domain	Sedentary activities			Sensory room			<i>p</i> -value (for change comparison)	Effect size (<i>r</i>)
	Pre-intervention	Post-intervention	Change (Post–Pre)	Pre-intervention	Post-intervention	Change (Post–Pre)		
Anger/hostility	49.80 (2.56)	42.55 (1.38)	-7.25 (2.19)	47.00 (2.10)	40.75 (1.32)	-6.25 (1.80)	.698	-.087
Confusion/bewilderment	60.95 (3.15)	52.30 (2.69)	-8.65 (2.79)	56.30 (2.84)	47.20 (2.37)	-9.10 (2.10)	.896	-.029
Depression/dejection	59.45 (2.77)	51.35 (2.34)	-8.10 (1.40)	57.95 (2.63)	49.60 (2.12)	-8.35 (2.30)	.744	-.073
Fatigue/inertia	55.05 (2.45)	46.70 (2.50)	-8.35 (2.20)	53.15 (2.66)	40.30 (1.96)	-12.85 (2.64)	.210	-.280
Tension/anxiety	57.50 (2.70)	48.45 (2.33)	-9.05 (1.97)	54.30 (2.66)	42.30 (2.04)	-12.00 (2.06)	.096	-.372
Vigour/activity	45.55 (2.22)	49.10 (2.15)	3.55 (1.36)	46.70 (1.82)	48.65 (1.69)	1.95 (1.62)	.486	-.156
Friendliness	47.05 (1.80)	43.60 (1.70)	-3.45 (1.84)	49.55 (1.60)	47.30 (1.61)	-2.25 (1.56)	.519	-.144
Total mood disturbance	57.80 (2.76)	48.30 (2.35)	-9.50 (1.84)	54.70 (2.46)	43.90 (2.09)	-10.80 (2.03)	.793	-.059

Note. $N = 20$. Values are presented as Mean (Standard Error). Wilcoxon signed-rank tests with Bonferroni correction; the significance level was

set at $p < .0063$.

Table 3

Changes in scores on the Multidimensional Assessment of Interceptive Awareness (MAIA).

MAIA domain	Sedentary activities			Sensory room			<i>p</i> -value (for change comparison)	Effect size (<i>r</i>)
	Pre-intervention	Post-intervention	Change (Post–Pre)	Pre-intervention	Post-intervention	Change (Post–Pre)		
Noticing	2.39 (0.23)	2.39 (0.24)	0.00 (0.24)	2.69 (0.24)	3.25 (0.17)	0.56 (0.26)	.092	-.377
Not-Distracting	2.12 (0.23)	2.85 (0.27)	0.73 (0.24)	2.28 (0.16)	2.88 (0.23)	0.60 (0.26)	.827	-.049
Not-Worrying	2.03 (0.28)	2.37 (0.24)	0.33 (0.25)	2.00 (0.19)	3.05 (0.25)	1.05 (0.28)	.004	-.653
Attention Regulation	2.61 (0.19)	2.64 (0.21)	0.04 (0.21)	2.54 (0.16)	3.27 (0.19)	0.74 (0.18)	.056	-.428
Emotional Awareness	2.61 (0.19)	2.81 (0.20)	0.20 (0.19)	2.60 (0.21)	3.36 (0.14)	0.76 (0.20)	.056	-.427
Self-Regulation	2.55 (0.24)	2.74 (0.23)	0.19 (0.15)	2.25 (0.23)	3.19 (0.18)	0.94 (0.21)	.013	-.556
Body Listening	1.92 (0.21)	2.33 (0.21)	0.42 (0.16)	2.05 (0.29)	2.68 (0.16)	0.63 (0.22)	.340	-.213
Trusting	2.03 (0.25)	2.35 (0.18)	0.32 (0.16)	2.27 (0.27)	3.12 (0.17)	0.85 (0.24)	.036	-.468

Note. $N = 20$. Values are presented as mean (standard error). Wilcoxon signed-rank tests with Bonferroni correction; the significance level was set

at $p < .0063$. Significant results are shown in **bold**.