

Associations Among Hypersensitivity, Vagal Tone, and Mood State in Adults

（成人における感覚過敏および迷走神
経活動、気分状態の関連性）

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Associations Among Hypersensitivity, Vagal Tone, and Mood State in Adults

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OTJR: Occupational Therapy Journal of Research
1–9

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DOI: 10.1177/15394492241259402

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Abstract

Although many previous studies have reported the relationship between hypersensitivity and vagal function in children, the relationship in adults is unclear. This study investigates the relationship between hypersensitivity and vagal function, discomfort to sensory stimuli, and daily mood states in healthy adults. Using a questionnaire, 39 healthy adults were divided into hypersensitivity and control groups. We compared the baseline respiratory sinus arrhythmia (RSA), reflecting vagal tone and reactivity, subjective discomfort to sensory stimuli, and daily mood status between groups. Those in the hypersensitivity group had significantly lower baseline RSA and were more likely to experience greater RSA variability and discomfort during exposure to sensory stimuli than the control group. We found no significant difference between groups in daily mood status. These findings suggest that vagal function is an important marker of hypersensitivity in healthy adults.

Plain Language Summary

Relationships Among Hypersensitivity, Parasympathetic Function, and Mood States in Adults

Previous studies in children have reported many associations between sensory characteristics, such as hypersensitivity to sensory stimuli, and parasympathetic function, but the association in adults is not clear. This study divided 39 healthy adults into a hypersensitivity group and a control group and compared their parasympathetic function, discomfort to sensory stimuli, and daily mood. We found that the hypersensitivity group had significantly lower baseline parasympathetic function and tended to experience greater fluctuations in parasympathetic activity and discomfort during sensory stimulation than the control group. However, we found no significant difference in daily mood between the groups. This suggests that parasympathetic function is an important marker of hypersensitivity in healthy adults. This may help therapists support those with hypersensitivity. Future research is needed in clinical practice.

Keywords

hypersensitivity, sensory process, vagal tone, respiratory sinus arrhythmia, mood

Individuals exhibit differences in responding to light, sound, and other sensory stimuli, such as hypersensitivity and insensitivity. Children with developmental disabilities and adults with mental disorders may both present atypical sensory processing (Thye et al., 2018; van den Boogert et al., 2022). Healthy individuals may also have atypical sensory experiences (Brown et al., 2001). These characteristics are associated with atypical autonomic activity and difficulties in daily living (Bar-Shalita & Cermak, 2016; DeBoth et al., 2023), so characterizing the neurophysiology of sensory processing is important.

Atypical Sensory Processing

Dunn (1997) proposed a four-quadrant concept of sensory processing with two axes: neurological threshold and behavioral response. A low neurological threshold indicates that

neurons fire with low-intensity stimuli, whereas a high neurological threshold indicates the opposite. The four quadrants comprise the two thresholds and passive or active behavioral responses to certain conditions. A low threshold and passive behavioral response implies a condition called “sensory sensitivity,” while a high threshold implies “low registration.” A low threshold and active sensory stimuli

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avoidance is classified as “sensation avoiding,” whereas a high threshold and sensory stimuli seeking is categorized as “sensation seeking” (Brown et al., 2001). Sensory modulation disorder (SMD) occurs when atypical sensory processing interferes with daily life (Miller et al., 2007).

Dunn (1997) referred to a low threshold for sensory stimuli as hypersensitivity or sensory over-responsivity. Hypersensitivity is characterized by prolonged or exaggerated responses to stimuli such as loud and unpredictable sounds, environments involving high visual stimuli, and the taste, smell, and texture of certain foods (James et al., 2011; Reynolds & Lane, 2008). Hypersensitivity is present in 5%–15% of healthy samples (Ahn et al., 2004) and is associated with increased psychological distress (Bar-Shalita & Cermak, 2016).

Hypersensitivity and the Autonomic Nervous System

Hypersensitivity is related to physiological indices in the pediatric field. Developing a sensory challenge protocol (SCP), Miller et al. (1999) reported that children with hypersensitivity exhibit greater sympathetic response to specific stimuli. Schaaf et al. (2010) measured vagal activity in children using the SCP task and reported that children with severe SMD tended to have a low baseline vagal tone (i.e., not relaxed during rest) and transiently increased vagal activity (i.e., disturbance in the autonomic nervous system) during sensory stimulus exposure. DeBoth et al. (2023) classified children with autism spectrum disorder into sensory-based subtypes, investigating differences in physiological response (e.g., respiratory sinus arrhythmia [RSA]) to sensory input from the SCP, reporting that those with atypical sensory processing, including hypersensitivity and hyporesponsiveness, had lower RSA at rest but elevated RSA during tactile and auditory stimulation. These previous studies suggest that hypersensitivity is associated with autonomic nervous system function.

Autonomic Nervous System

The autonomic nervous system, which comprises the sympathetic and parasympathetic nervous systems (PsNS), controls the heart rate. The vagus nerve has a major role in producing heart rate variability (HRV; Arakaki et al., 2023; Taylor et al., 2022). In frequency domain HRV measurements, heart rate periodicity can be divided into high (HF, 0.15–0.4 Hz) and low frequencies (LF, 0.04–0.15 Hz), related to both vagal and sympathetic activity and other unidentified components (Arakaki et al., 2023; Shaffer & Ginsberg, 2017). Frequencies associated with spontaneous breathing (i.e., high-frequency HRV) are also referred to as RSA, caused by the effects of breathing feedback from the lung stretch receptors and feed-forward from the respiratory neuron centers (Taylor et al.,

2022). RSA amplitude reflects the degree to which the vagus nerve, which mediates input from the brain to the heart, inhibits the heartbeat (Lewis et al., 2012; Porges, 2007). Resting RSA and RSA variability in response to stressors are widely used as PsNS activity indicators (Hinnant & El-Sheikh, 2009; Porges, 2007; Weissman & Mendes, 2021).

Relationships Between Hypersensitivity and Autonomic Nervous System, Subjective Emotions, and Mood

Emotion is a short-term psychological response triggered by an event; a mood, such as depression or anxiety, is a persistent affective state predominated by a particular type of subjective feeling (Scherer, 2005). A higher baseline RSA and a greater decrease in RSA during stressful stimuli is associated with better emotion regulation (Calkins & Keane, 2004; Thayer & Lane, 2009). Conversely, a low baseline RSA is associated with emotional regulation difficulties and psychiatric disorders (Porges, 2007). Higher “sensory sensitivity” and “sensation avoiding” traits (based on Dunn, 1997), meaning hypersensitivity, are correlated with higher depression, impulsivity, emotional loss, and trait and state anxiety (Engel-Yeger & Dunn, 2011; Serafini et al., 2017).

Thayer and Lane (2000, 2009) proposed a neurovisceral integration model of heart and brain activity in which the prefrontal cortex and limbic system control HRV. They suggest that vagal activity regulates the sinus node of the heart and mediates the prefrontal cortex, thereby regulating physiological and autonomic responses and influencing human behavior (Cattaneo et al., 2021). Vagal activity may be closely related to hypersensitivity, subjective emotions, mood, and stress.

Gaps in Existing Literature

Many studies have investigated the relationship between hypersensitivity and vagal function in children (DeBoth et al., 2023; Miller et al., 1999; Schaaf et al., 2010), but the relationship between hypersensitivity and vagal function in adults remains unclear.

The Study Objective

This study investigates the relationship between hypersensitivity and vagal function in healthy adults. In addition, we investigate the relationship between hypersensitivity, objective physiological responses, subjective emotions in response to sensory stimuli, and daily mood states. By investigating parasympathetic activity features and mood states in healthy adults with low sensory stimulation thresholds, we can elucidate the underlying mechanisms of hypersensitivity.

Our hypotheses are as follows:

1. Healthy adults with features of hypersensitivity have a lower vagal tone at rest than those without.
2. Healthy adults with hypersensitivity show greater fluctuations in vagal activity during sensory stimulus exposure than those without.
3. Healthy adults with hypersensitivity have more negative emotions in response to sensory stimuli than those without.
4. Healthy adults with hypersensitivity experience negative and positive mood states more and less frequently, respectively, in daily life than those without.

Materials and Methods

Participants

The study participants included 39 healthy adults (20 male, 19 female, 21.6 ± 0.3 years old). Participants were university students recruited from the author's institution via the university's website. The recruitment bulletin board on the website displayed the experiment description and conditions for participation. Prospective participants had to be Japanese university students over the age of 18 years with no history of psychiatric or cardiac disease and no obvious organic or functional abnormalities in vision, hearing, touch, smell, or taste. The research team received a total of 42 applications, of which three were canceled or the applicants could not be contacted before commencement, leaving 39 participants who met the participation criteria and could be reached for data collection.

The hypersensitivity group comprised participants who scored "More Than Most People" or "Much More Than Most People" in sensory sensitivity (score ≥ 43) or sensation avoiding (score ≥ 42) characteristics according to the Adolescent/Adult Sensory Profile (AASP) manual criteria. The control group participants had scores below this benchmark. Participants' characteristics are presented in Supplemental Table 1. There were no significant differences in sex, age, years of education, intelligence quotient (IQ), or autistic tendencies between groups. We fully briefed all participants before the experiment began, and they provided verbal and written consent.

Procedure

In a quiet, comfortable room (temperature: $22.6 \pm 0.2^\circ\text{C}$, humidity: $24.5\% \pm 1.0\%$), the participants completed a questionnaire providing basic demographic data. Next, they completed the AASP questionnaire and provided RSA measurements during the SCP and Profile of Mood States 2nd Edition (POMS2).

Measures

Sensory Profile. We used the Japanese version of the AASP to assess the tendency for sensory processing. This

self-administered questionnaire assesses behavioral responses related to daily sensory processing in participants aged 11 years or older. Brown and Dunn (2015) standardized the questionnaire using a survey of 1,198 participants, finding it to have adequate reliability and validity. The questionnaire assesses the degree of "low registration," "sensation seeking," "sensory sensitivity," and "sensation avoiding" based on Dunn's (1997) model. The questionnaire comprises 8–13 items in six categories—taste/smell, movement, visual, touch, activity, and auditory—for a total of 60 items, each rated on a 5-point Likert-type scale (almost never to almost always). The score for each characteristic ranges from 15 to 75, with higher scores indicating a higher characteristic level.

Measurement of RSA During the SCP. Miller et al. (1999) developed the SCP to measure children's physiological responses during sensory stimulus exposure. We adapted the task in this study from Miller et al. (1999) and Schaaf et al. (2010); we included a resting period (3 min), six types of sensory stimuli (tone, visual, siren, olfactory, tactile, and vestibular), a recovery period (3 min), and a prolonged auditory stimulus (2 min). The tone, visual, and siren tasks consisted of an 84-dB and 1.7-Hz alarm tone, 20-W and 10-Hz flashing light, and 78-dB fire siren, respectively. The olfactory task involved the examiner standing to the left of the participant and holding a bottle of wintergreen oil 2 cm under the participant's nose. In the tactile task, the examiner touched the participant's chin with a feather measuring approximately 2 cm by 7 cm, moving it from left to right for approximately 3 s. For the vestibular task, the examiner stood behind the reclining chair where the participant was sitting and tilted the back of the chair 30 degrees for 1 s, held the tilted position for 1 s, then returned it to the original position for 1 s. The prolonged auditory task consisted of a continuous sound at 75 dB. Other than the prolonged auditory task, each stimulus lasted for approximately 3 s. There were random intervals of 12–17 s between stimuli, and each stimulus was repeated eight times. The video showed the fixation point, the auditory and visual stimuli, and the timing of the other stimuli. Before the SCP began, we described each stimulus and told participants to look at the fixation point on the display. Unlike the original task (Miller et al., 1999), this study included no verbal interaction between the experimenter and participants during the experiment. A single examiner performed all experiments with blinded groupings.

We used a portable pulse-wave measuring device, Polypul (PCG) II (Nihonsanteku, Osaka, Japan), to measure photoplethysmogram waveforms, which were acquired with a 1000-Hz sampling rate. A licensed author (K.I.) at CardioEdit (Brain-Body Center, University of Illinois, Chicago) visually determined and corrected noise in the time-series data, such as sudden spikes. CardioBatch (Brain-Body Center, University of Illinois, Chicago), which implements the

Porges–Bohrer (PB) method (Porges & Bohrer, 1990), quantified the RSA. The PB method excludes the nonstationary components of physiological data and extracts only the frequencies associated with spontaneous breathing. As previous studies have suggested a relationship between vagal function and hypersensitivity (DeBoth et al., 2023; Schaaf et al., 2010), we selected the PB method to address our research objectives. First, a moving polynomial filter removes nonstationary components and periodic effects, such as blood pressure variations, which are slower than spontaneous breathing. Second, multiple RSA estimates are generated in short-time epochs of 30 s. Finally, the variance of each epoch is transformed to the natural logarithm (units = $\ln[\text{ms}^2]$) to move the data closer to the normal distribution assumption; the multiple epoch values are averaged. As a result, this method is more sensitive to vagal activity than other frequency- and time-domain measures (Lewis et al., 2012; Porges, 2007; Porges & Bohrer, 1990).

We calculated RSA values for each of the SCP's phases: resting period, six types of sensory stimulation, recovery, and prolonged auditory stimulation. We measured the subjective discomfort level for each SCP modality on an 11-point Likert-type scale ranging from 0 (not at all discomforting) to 10 (extremely discomforting).

Profile of Mood States 2nd Edition. The POMS2 is a standardized self-administered questionnaire assessing mood states that comprises seven scales: “anger/hostility,” “confusion/bewilderment,” “depression/dejection,” “fatigue/inertia,” “tension/anxiety,” “vigor/activity,” and “friendliness.” Total mood disturbance (TMD) is a composite of seven scales, each calculated as a T-score. This study focused on sustained emotional states in the past week. We used the Japanese version of the all-item version (65 items) for adults, and participants responded to each item on a 5-point Likert-type scale ranging from 0 (*not at all*) to 4 (*very much*) (Heuchert & McNair, 2012).

Demographic Information. Demographics included age, sex, years of education, IQ, and autism spectrum quotient (AQ). We included IQ and AQ in response to the findings of Kushki et al. (2014) which revealed that features of autism spectrum disorder and IQ are related to vagal function. Our aim was to confirm that there were no differences in such features between the two groups. We assessed IQ using the Japanese adult reading test.

Data Analysis

The data were analyzed using IBM SPSS Statistics version 29 (IBM, Armonk, New York) with a significance level of $p < .05$. All participants ($n = 39$) were included in the analysis. We compared basic information (age, years of education, IQ, and AQ) between groups using the Mann–Whitney U-test and Pearson's chi-square test for the sex ratio. We used unpaired

t -tests to compare the AASP score. First, we compared baseline RSA between the hypersensitivity and control groups using unpaired t -tests. Next, we conducted repeated-measures two-way analyses of variance (ANOVAs) to examine the effects of groups and SCP domains. The first ANOVA assessed changes from baseline RSA across eight domains, while the second analyzed raw scores of subjective discomfort across SCP domains. Furthermore, we compared POMS2 scores (T-scores) between the groups using the Mann–Whitney U-test. For ANOVA, we confirmed the sphericity assumption for the subjective discomfort score using Mauchly's sphericity test. Because sphericity could not be assumed for the change from the baseline RSA, we corrected the significance probability of the within-subjects effect test using the Greenhouse–Geisser test. We used the Shapiro–Wilk test to confirm normality.

Results

AASP Scores

Supplemental Table 2 presents the AASP quadrant scores.

Baseline RSA

Figure 1 shows a comparison of the RSA values for the two groups during SCP.

Figure 2 presents a comparison of baseline RSA between the two groups. The hypersensitivity group has significantly lower RSA values than the control group ($p < .001$, $d = 1.57$).

The Change From Baseline RSA in SCP

The change from baseline RSA in each SCP domain between the two groups and SCP domain repeated-measures two-way ANOVA showed a main effect between groups, $F(1, 37) = 6.76$, $p = .013$, $\eta^2 = 0.154$, with the hypersensitivity group having a greater increase in RSA during stimulation than the control group. We also found a main effect in the sensory SCP domain, $F(4, 164) = 4.72$, $p < .001$, $\eta^2 = 0.113$; however, there was no interaction effect between groups and sensory domains, $F(4, 164) = 0.62$, $p = .67$, $\eta^2 = 0.016$. The changes from the baseline RSA in SCP are shown in Figure 3.

Subjective Discomfort Levels for SCP

A repeated-measures two-way ANOVA between the two groups and SCP domains on the subjective discomfort score (raw score) of each domain of the SCP showed main effects in the sensory domain of the SCP, $F(6, 222) = 18.71$, $p < .001$, $\eta^2 = 0.336$, and between groups, $F(1, 37) = 8.02$, $p = .007$, $\eta^2 = 0.178$. However, there was no interaction effect between groups and sensory domains, $F(6, 222) = 0.68$, $p = .67$, $\eta^2 = 0.018$. Subjective discomfort levels for SCP are shown in Figure 4.

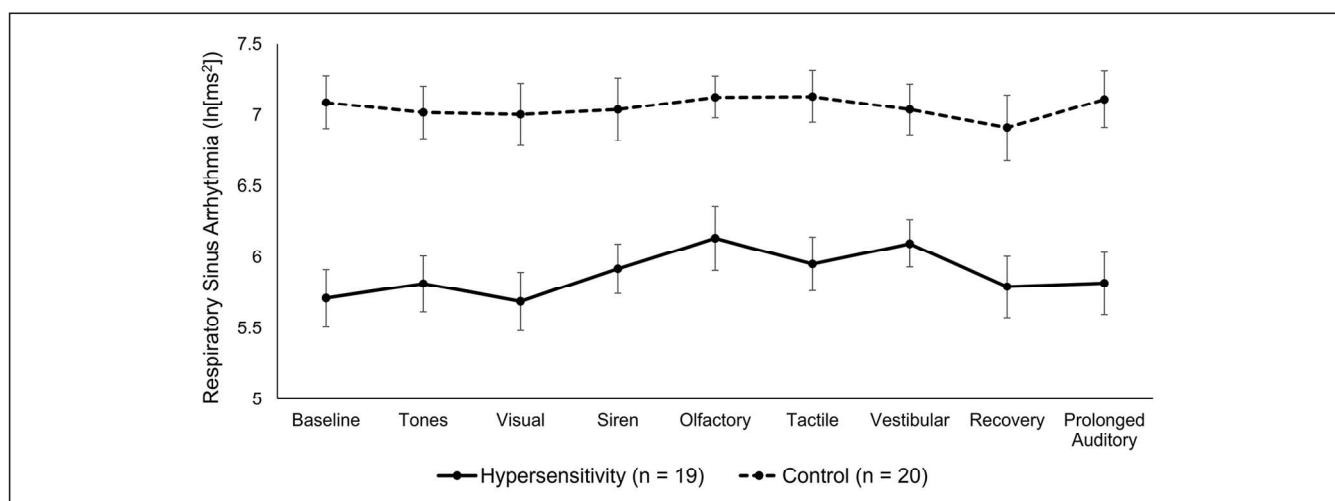


Figure 1. RSA Values During SCP in the Two Groups (N = 39)
 Note. Plots show mean values and error bars indicate standard errors.

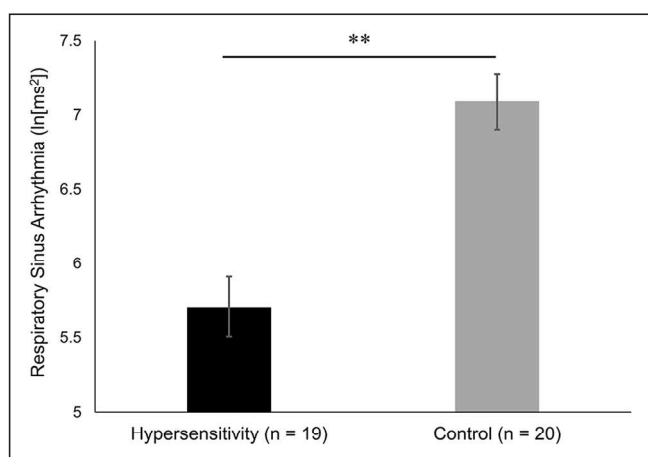


Figure 2. Comparison of Baseline RSA of the Two Groups (N = 39)
 Note. Bars indicate mean values for each group, error bars indicate the standard error, and the two asterisks indicate $p < .01$.

POMS2 Scores

Table 1 shows a comparison of T-scores for each domain of POMS2 between the two groups. No significant differences were observed between the groups for any of the items.

Discussion

This study examined the relationship between hypersensitivity and vagal function in healthy adults. We also investigated the relationship between hypersensitivity and objective physiological responses to sensory stimuli, subjective emotions, and daily mood state.

Vagal Function of Hypersensitivity

The hypersensitivity group had significantly lower RSA values than the control group (Figure 2), indicating that adults with low sensory thresholds according to the AASP have a lower vagal tone than those with a higher threshold. This is consistent with the results of DeBoth et al. (2023) and Schaaf et al. (2010) and supports our first hypothesis that healthy adults with hypersensitivity have lower resting vagal tone than those without. We found a main effect of group on the change in RSA of each SCP domain from baseline rest (Figure 3). This supported both previous studies (DeBoth et al., 2023; Schaaf et al., 2010) and our second hypothesis that the control group's RSA would be almost unchanged or decreased during SCP stimulation, while the hypersensitivity group would have an increased RSA.

These results suggest that individuals with hypersensitivity traits have low vagal tone at rest and increased vagal activity upon exposure to sensory stimuli. Therefore, these results might reflect an aspect of sensory processing derived from vasovagal syncope (Alboni & Alboni, 2017), although detailed psychophysiological studies to confirm this finding are needed in the future.

Spangler and McGinley (2020) investigated vagal reactivity during a cognitive task involving social and emotional auditory disturbance stimuli and reported that greater vagal flexibility (i.e., adequate inhibition of vagal activity) was associated with greater performance stability. Therefore, when hypersensitive individuals encounter sensory stimuli in daily life, they might experience difficulties in performing cognitive activities due to insufficient inhibition of vagal function.

There were no interaction effects between the two groups and SCP domains for changes from the baseline RSA in each

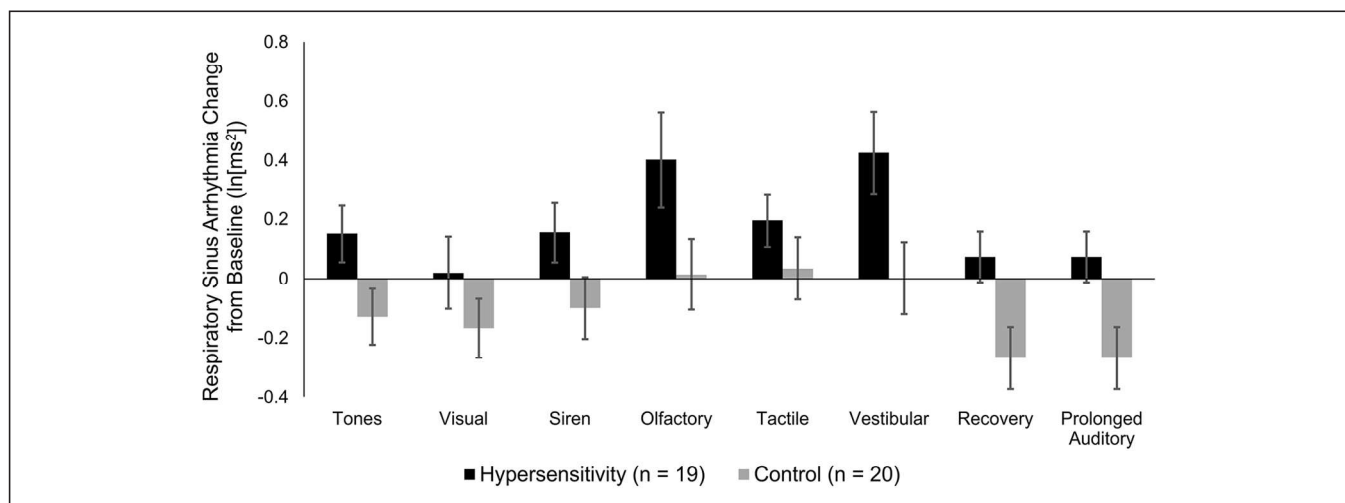


Figure 3. The Change From Baseline RSA in SCP (N = 39)

Note. Bars show the mean value per group of RSA changes from baseline to each domain of the SCP. Error bars represent the standard error.

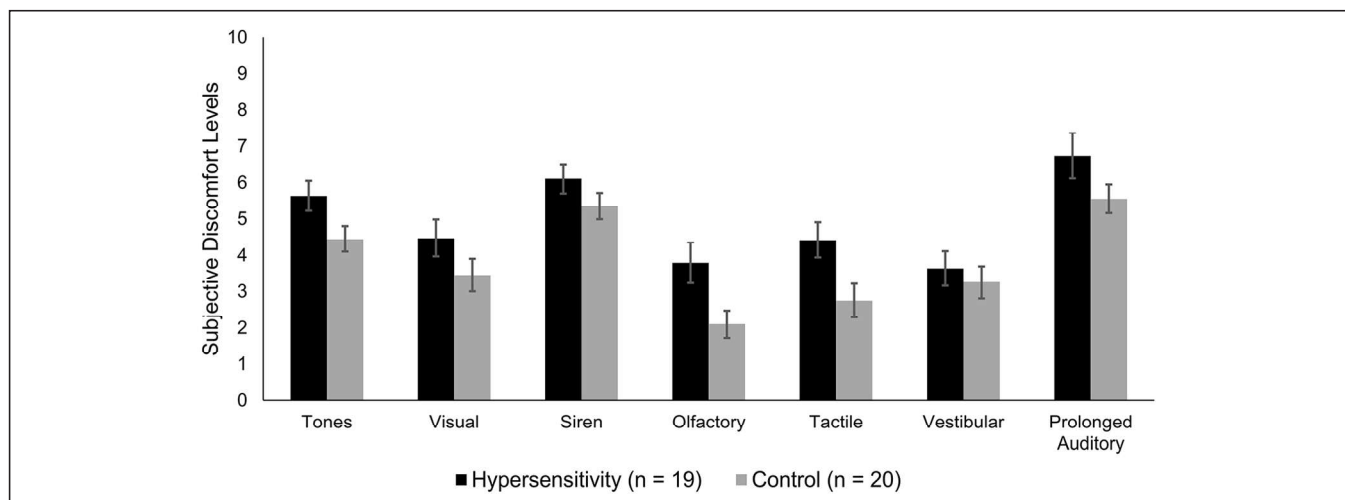


Figure 4. Subjective Discomfort Levels for SCP (N = 39)

Note. The bars indicate the average subjective discomfort score per group for each SCP domain. Error bars represent the standard error.

SCP domain. A previous study using the same sensory stimuli reported that children with SMD had elevated RSA specifically in tactile and auditory senses (DeBoth et al., 2023), which did not support the results of this study. However, differences in grouping criteria regarding the hypersensitivity group may have influenced the results. In addition, sensory thresholds increase with age (Ueno et al., 2019), and the underlying mechanism may be related to an increase in prefrontal regulation of the amygdala with aging (Green et al., 2019).

Subjective Discomfort Levels for Sensory Stimuli of Hypersensitivity

The main effect of groups shows that the hypersensitivity group had significantly higher subjective discomfort (Figure 4), supporting our third hypothesis. In a functional magnetic

resonance imaging study investigating hypersensitivity brain activity during exposure to auditory and tactile mildly aversive sensory stimuli, those with high hypersensitivity showed higher subjective discomfort during exposure to stimuli than those with low hypersensitivity (Green et al., 2019). In previous studies, higher vagal activity was associated with stronger amygdala-medial prefrontal cortex coupling and better emotion regulation, whereas lower HRV was associated with impaired emotion regulation, such as anxiety (Arakaki et al., 2023; Cattaneo et al., 2021). Increased vagal reactivity in response to emotional stimuli reflects self-regulation efforts or recovery from stress (Balzarotti et al., 2017). Therefore, hypersensitive individuals might be challenged to regulate their emotions when they experience sensory stimuli that are inconsistent with their sensory preferences.

Table 1. Comparison of T-Scores for Each Domain of POMS2 (N = 39).

POMS2 domain	Mean $\pm$ SE		p-value	Effect size, <i>r</i>
	Hypersensitivity (<i>n</i> = 19)	Control (<i>n</i> = 20)		
Anger/hostility	45.95 $\pm$ 2.34	43.30 $\pm$ 1.03	.74	−0.05
Confusion/bewilderment	53.58 $\pm$ 2.73	51.10 $\pm$ 1.66	.60	−0.08
Depression/dejection	51.26 $\pm$ 2.00	48.75 $\pm$ 1.27	.40	−0.14
Fatigue/inertia	51.05 $\pm$ 1.75	47.35 $\pm$ 2.00	.10	−0.26
Tension/anxiety	52.00 $\pm$ 2.51	52.15 $\pm$ 1.95	.87	−0.03
Vigor/activity	54.16 $\pm$ 2.67	56.60 $\pm$ 2.15	.33	−0.16
Friendliness	51.58 $\pm$ 2.72	55.80 $\pm$ 1.97	.21	−0.20
Total mood disturbance	49.68 $\pm$ 2.41	47.10 $\pm$ 1.55	.33	−0.16

Note. Mean $\pm$ standard error of the scores per POMS2 item for the hypersensitivity and control groups and the p-value and effect size of the Mann–Whitney U test.

However, we found no interaction effect between the two groups and SCP domains in the subjective discomfort score (raw score) for each SCP domain. Similar to the vagal reactivity results, grouping criteria may have had an effect. In addition, considering that the SCP was created for children, it is possible that the stimuli had a weaker effect on healthy adults.

Relationship Between Hypersensitivity and Mood State

The results of between-group comparisons of POMS2 subtests and TMD scores did not support the fourth hypothesis, as there were no significant differences between the groups for any of the items (Table 1). The AASP, used for grouping in the present study, asks about daily behavioral responses related to sensory processing (Brown & Dunn, 2002). By contrast, the POMS2 assesses relatively long-lasting emotional states (Heuchert & McNair, 2012). Differences between the POMS2 and the AASP may be why this study found no association. In our study, the POMS2 asked participants about their mood state over a week, which can vary. As Bar-Shalita and Cermak (2016) associated atypical sensory processing with psychological distress, further investigations using psychometric indices less susceptible to irregular daily stressors are needed.

Implications for Occupational Therapy

The results contribute to the elucidation of the neurophysiological mechanisms of hypersensitivity and may contribute to assessment and support for people with hypersensitivity characteristics, such as auditory hypersensitivity. This study showed the importance of utilizing the tendency for sensory processing in occupational therapy for adults. Understanding the relationship between RSA and hypersensitivity will contribute to using RSA as a potential biomarker for atypical sensory processing. Therapists and clinicians could use it to

assess the tendency for sensory processing in clients who have difficulty self-reporting.

We believe that using assessments and interventions focusing on hypersensitivity and vagal activity in occupational therapy will enable participants to engage in occupational activities while maintaining appropriate autonomic function in their daily lives, leading to a reduction in psychological stress and a better social life.

Limitations and Future Research

There are several limitations to this study. The AASP can assess sensory processing patterns in everyday life, but it relies on subjective self-reporting. The AASP scores of the sample population tended to be higher than those of the standardized sample in “sensory sensitivity” and “sensation avoiding.” The ratings of POMS2 and SCP are also subjective. The examiner manually stimulated the SCP’s olfactory, tactile, and vestibular tasks, making it difficult to completely control the amount of stimulation. Therefore, caution is needed when interpreting these results. This study focused on healthy adults; HRV may be affected by medications such as selective serotonin reuptake inhibitors (Fiani et al., 2023), and this study aimed to investigate the association between parasympathetic function and hypersensitivity in an unmedicated state. Atypical sensory processing is widely biased in individuals with mental disorders (Bailliard & Whigham, 2017; van den Boogert et al., 2022) and may be associated with reduced parasympathetic function in this population. Future clinical studies should extend this study to a clinical setting. In addition, the present study did not focus on the differences in response by sensory modality or degree of habituation to sensory stimuli. The SCP had insufficient washout time between sensory domains, which could have resulted in discomfort experienced during one sensory stimulus being carried over to the next sensory stimulus. Hypersensitivity is problematic because of difficulties in habituating to sensory stimuli and during exposure to

multisensory stimuli (Gonçalves & Monteiro, 2023; Lane et al., 2019). Therefore, further investigations focusing on comparisons between sensory domains and habituation and multisensory stimuli are required.

Conclusion

This study investigates the relationship between hypersensitivity and vagal function in healthy adults and examines the association between hypersensitivity and objective physiological responses to sensory stimuli, subjective emotions, and daily mood states. The results show that adults with hypersensitivity characteristics have a lower baseline vagal tone and larger fluctuations in vagal activity in response to stimuli than those without. In addition, they are likely to experience discomfort when exposed to sensory stimuli. However, we find no difference between the two groups in terms of daily mood state. The results of this study help elucidate the mechanisms of sensory processing and the vagus nervous system and examine the support and intervention effectiveness for people with atypical sensory processing who experience difficulty in living their daily lives.

Acknowledgments

The authors gratefully acknowledge all the participants in this study.

Ethical Approval

This study was approved by the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (Approval No. R2819-1). All participants were fully informed in advance, and written and verbal consent was obtained.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was partially supported by grants from the Japan Society for the Promotion of Science (Grant-in-Aid for Young Scientists, 22K17631 to KI) and the Kyoto University internal grant SPIRITS (to KI).

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Supplemental Material

Supplemental material for this article is available online.

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Supplemental Table 1

Participant Characteristics (N = 39).

Characteristics	Mean $\pm$ SE or n		p-value	Effect size r or ϕ
	Hypersensitivity (n = 19)	Control (n = 20)		
Male	10	10	0.87	0.03
Female	9	10		
Age	21.95 $\pm$ 0.53	21.20 $\pm$ 0.46	0.39	-0.14
Educational level	14.84 $\pm$ 0.54	14.35 $\pm$ 0.40	0.63	-0.08
Intelligence Quotient	114.32 $\pm$ 1.10	112.50 $\pm$ 1.29	0.27	-0.18
Autism spectrum quotient	22.16 $\pm$ 1.83	19.90 $\pm$ 1.64	0.50	-0.11

Supplemental Table 2

Comparison of AASP Scores (N = 39).

AASP domain	Mean $\pm$ SE		p-value	Cohen's d
	Hypersensitivity (n = 19)	Control (n = 20)		
Low registration	34.00 $\pm$ 1.66	31.80 $\pm$ 1.95	0.40	-0.27
Sensation seeking	40.79 $\pm$ 1.52	39.75 $\pm$ 2.12	0.70	-0.13
Sensory sensitivity	46.53 $\pm$ 1.42	33.50 $\pm$ 1.34	<.001	-2.14
Sensation avoiding	45.05 $\pm$ 1.53	32.55 $\pm$ 1.41	<.001	-1.93