Routledge
Taylor & Francis Group

Journal of Clinical and Experimental Neuropsychology

ISSN: 1380-3395 (Print) 1744-411X (Online) Journal homepage: www.tandfonline.com/journals/ncen20

Attention and physiological responses to task-irrelevant sounds in misophonia

Louisa J Rinaldi, Romarua Agbude, Nora Andermane, Dominique Makowski, Sophie Forster, Julia Simner & Jamie Ward

To cite this article: Louisa J Rinaldi, Romarua Agbude, Nora Andermane, Dominique Makowski, Sophie Forster, Julia Simner & Jamie Ward (2026) Attention and physiological responses to task-irrelevant sounds in misophonia, Journal of Clinical and Experimental Neuropsychology, 48:3, 266-280, DOI: 10.1080/13803395.2026.2633236

To link to this article: https://doi.org/10.1080/13803395.2026.2633236

JOURNAL OF CLINICAL AND EXPERIMENTAL NEUROPSYCHOLOGY
2026, VOL. 48, NO. 3, 266–280
https://doi.org/10.1080/13803395.2026.2633236

Attention and physiological responses to task-irrelevant sounds in misophonia

Louisa J Rinaldi, Romarua Agbude, Nora Andermane, Dominique Makowski, Sophie Forster, Julia Simner and Jamie Ward

School of Psychology, University of Sussex, Brighton, UK

ABSTRACT

Introduction: Misophonia is a disorder in which certain sounds (known as triggers) cause a negative and often overwhelming emotional response. Common triggers include human-produced and repetative sounds such as chewing and tapping. The extent to which this response is modulated by task focus – such as whether a sound is attended or not – is largely unknown. Similarly, the extent to which these responses are specific to triggers or found, to some degree, for a wider range of stimuli is unclear.
Methods: In this study, two groups (misophonics, controls) engage in a visuo-motor task during the presence of irrelevant sounds (misophonic triggers, unpleasant sounds, neutral sounds) whilst the effects of distraction (poorer performance in the visuo-motor task) and psychophysiological responsiveness (heart and skin conductance) are measured.
Results: The results show that misophonic triggers elicit more distraction than other sounds (for people with misophonia), but this is set against a backdrop of an overall tendency for people with misophonia to be more distracted by all sounds. We found no differences in skin conductance, but significant group differences in heart rate and heart rate variability across both sounds and silence.
Conclusions: These findings suggest that misophonia is linked to trait-like differences in attentional style and emotional regulation.

ARTICLE HISTORY
Received 12 May 2025
Accepted 13 February 2026

KEYWORDS
Attention; skin conductance; heart rate variability; HRV; misophonia

Misophonia is a sound sensitivity disorder in which certain sounds (known as triggers) cause a negative and often overwhelming emotional response. Misophonic trigger sounds tend to include human-produced sounds that often originate from the nose and mouth, including eating noises (e.g., chewing, swallowing, crunching, sniffing), but can also be repetitive ambient sounds (e.g., tapping, pen clicking). For people with misophonia, the typical emotional response includes anger, disgust or anxiety (Swedo et al., 2021), which could be potentially defined objectively as well as psychologically. Many studies have explored misophnonics' heightened responses to sounds (triggers and/or non-triggers) through a variety of methods including subjective rating scales (Ghorbani et al., 2023; Simner et al., 2022), psychophysiological responses in the body such as heart or electrodermal activity/skin conductance (Edelstein et al., 2013; Siepsiak et al., 2023) or measures of brain activity including EEG and fMRI (Kumar et al., 2017; Schröder et al., 2019). In these studies, the participants' focus of attention is on the sounds themselves (i.e., sounds are either task-relevant or task-neutral in the case of passive listening). This is unlike real life where triggering sounds are encoutered whilst people with misophonia go about their daily lives. By contrast, in the current study, participants are engaged in an attention-demanding visuo-motor task and are asked to ignore sounds which are played infrequently and unpredictably (i.e., sounds are task-irrelevant). Responsiveness to the sounds is measured both behaviorally (in terms of slower or less accurate performance on the visuo-motor task) and in terms of psychophyiological responses. In this way, we can determine the extent to which misophonia is linked to intrusive attentional processes (and whether this is specific to trigger sounds or found for all stimuli), as well as physiological responses potentially indicating emotional dysregulation such as increased anxiety.

An early physiological study into misophonia by Edelstein et al. (2013) measured skin conductance during the presentation of 15s clips of visual, audio and audiovisual stimuli, including misophonic, unpleasant and neutral sounds. People with misophonia rated sounds as more aversive than the equivalent visual stimuli (e.g., chewing sounds vs. silent video of chewing), and skin conductance responses were increased

CONTACT Louisa J Rinaldi L.Rinaldi@sussex.ac.uk University of Sussex, Pevensey Building, Falmer, Brighton BN1 9RQ, UK
Supplemental data for this article can be accessed online at https://doi.org/10.1080/13803395.2026.2633236.

regardless of stimuli type. However, Kumar et al. (2017) found that stimuli type was important. They measured skin conductance and heart rate whilst participants listened to misophonic trigger sounds (e.g., chewing), generally unpleasant sounds for people with misophonia and controls (e.g., baby crying), and neutral sounds (e.g., rain). They found that people with misophonia had elevated heart rate and skin conductance for misophonic trigger sounds, but not for unpleasant or neutral sounds. By using concurrent fMRI, Kumaret al. (2017) found that activity in the anterior insular cortex (AIC) correlated with these physiological changes; that is, changes in brain-based mechanisms leads to greater autonomic arousal (via the sympathetic nervous system) detecable in the body. Similar fMRI and psychophysiological findings were reported by Schröder et al. (2019) during presentation of trigger and non-trigger audiovisual clips. The anterior insula is a key part of the salience network that detects interoceptive signals (e.g., from the heart) and generates subjective feeling states (Namkung et al., 2017). Heightened physiological responsiveness and AIC activity may typically function as an alerting mechanism (e.g., flagging a stimulus as risky) but, in the case of misophonia, can be construed as maladaptive (i.e., because most trigger sounds are not linked to any objective risk or threat). Siepsiak et al. (2023) played misophonic trigger sounds (e.g., eating, lip smacking) but varied the context (human oral, animal oral, human hands playing with mud). Context had a significant effect on subjective ratings but not on skin conductance measures (which showed overall higher responsiveness in misophonia) or heart rate (which showed no overall group difference, unlike earlier studies). Finally, whilst increases in heart rate and skin conductance are measures of arousal, increased heart rate variability (HRV) is often considered as a physiological marker of an increased ability to down-regulate this arousal (Reynard et al., 2011; Segerstrom & Nes, 2007). Thus, high HRV is linked to generally positive outcomes such as better emotion regulation and ability to cope with stress (Geisler et al., 2010; Kim et al., 2018). Grossini et al. (2022) found that misophonia was associated with lower HRV even in the rest period before the study (suggesting trait differences in this variable), with even greater group differences in this same direction (higher in controls, lower in misophonia) during sound presentation (see also Ferrer-Torres & Giménez-Llort, 2021). We test the hypothesis that people with misophonia exhibit lower HRV – interpreted as a correlate of emotion regulation deficits.

In our study we will examine the role of attention. Attention is the mechanism by which relevant information is selected via a process of competition (amongst competing tasks and stimuli) and irrelevant information is discarded (Chun et al., 2011). Misophonia could be explained by a difficulty in filtering out sounds (or trigger sounds specifically) either due to more top-down differences in task focus or differences in the bottom-up weighting given to these stimuli. Associating sensory stimuli (e.g., sounds) with high affective arousal is one way of biasing the competition in their favor (as discussed above), such that trigger sounds tend to become the focus of attention despite any efforts to ignore them. But there is also evidence that people with misophonia present with other trait differences in attention (i.e., which apply broadly across stimuli and situations) beyond the specific mechanism of triggers grabbing attention for themselves. In questionnaire measures, there is evidence of divergent profiles of attention in misophonia compared to controls (Ghorbani et al., 2023; Simner et al., 2022). Simner et al. (2022) found that people with misophonia self-reported greater attention-to-detail (with items such as "I tend to notice details that others do not"), and cognitive inflexibility (struggling to shift selectively between thoughts, e.g., "I dislike change"). Ghorbani et al. (2023) administered a measure of attentional control (questions concerning distraction and problems in attention switching) and found a significant correlation with the Misophonia Questionnaire (MQ; Wu et al., 2014). The measure of attentional control was found to be a mediator between MQ scores and measures of mental health and social disability. Importantly, these questionnaires are asking about everyday attention rather than to misophonic trigger sounds specifically. They suggest that misophonia is not simply a learned association between sound stimulus and affective response (e.g., Jastreboff & Jastreboff, 2023) but is an outcome of other trait differences that include individual differences in attention. Trait differences in basic cognitive mechanisms are often thought to underpin the emergence of complex disorders (e.g., in the RDoC, Research Domain Criteria, approach; Insel et al., 2010) and can explain why co-morbidities between disorders are common (because trait differences can operate trans-diagnostically; e.g., Borsboom, 2017).

Studies also show differences between people with misophonia and controls in more objective tests of attention (i.e., in which task performance is measured) across a range of stimuli. Simner et al. (2022) showed that worsening symptoms of misophonia (in terms of number and frequency of triggers) was significantly associated with increased accuracy in the Embedded

Figures task which is linked to attention-to-detail (identifying a simple shape hidden within a more complex design; Witkin et al., 1971). Silva and Sanchez (2019) looked at selective attention using the dichotic sentence identification task with either white noise or with misophonic sounds as task-irrelevant stimuli. They found that people with misophonia had poorer performance in sentence identification but only in the presence of the misophonic sounds (not during white noise). Abramovitch, Herrera, and Etherton (2024) found no group differences on a test of sustained visual attention (although within the misophonia group there was a link between severity and omission errors). Frank et al. (2019) used an attention network task (ANT) which involved making left/right responses to arrows following various kinds of cues (e.g., congruent and incongruent arrows) in a small sample of people with misophonia and controls ($n = 11$ in each group). Some blocks contained misophonic trigger sounds that were task irrelevant. People with misophonia had problems with alerting attention (i.e., sensitivity to incoming stimuli) but not orienting attention (i.e., aligning their attention to the source of the stimuli); importantly the effects were not dependent on sounds (i.e., no difference across blocks before versus during and after trigger-sounds).

These studies paint a mixed picture in which people with misophonia self-report and demonstrate superior attention to detail toward local stimuli, but there is mixed evidence regarding whether attention is disrupted by sounds. Furthermore, the extent to which attentional differences are specific to misophonic triggers is inconsistent across the studies. What *is* clear, however, is that people with misophonia have a physiological presentation when they hear trigger sounds, involving a divergent profile of skin conductance and heart rate, as well as clear differences in neurological function. However, *which* types of sounds trigger physiological acitvity, and the extent to which these findings are affected by task relevance and stimulus competition remains uncertain. The current study therefore aims to extend prior research by investigating the physiology of misophonia when misophonics are exposed to sounds while engaged in a sound-irrelevant task. In this way, we hope to capture a more ecologically realistic experience, in order to measure the physiological and attentional load of different types of sounds.

The current study resembles the everyday scenario of working on a computer keyboard and monitor (visuo-motor behavior) whilst intermittently encountering sounds that are not relevant to the task but have the potential to distract (e.g., someone eating nearby, or a passing ambulance). This is a variant of the Irrelevant Distratctor Task used elsewhere in the attention literature (e.g., Forster & Lavie, 2011). We hypothesized that across both people with misophonia and controls, they will be distracted by sounds (relative to silent trials), but anticipate that people with misophonia will be more distracted by, and have heightened physiological responses to, misophonic trigger sounds. The extent to which this is limited to just misophonic triggers or found, to some degree, for other sounds was a further important question alongside the time course of any performance difference (i.e., whether distraction is more long-lasting in misophonia).

Methods

The methods and analysis plan were pre-registered (https://osf.io/9g6fs) on the Open Science Framework (OSF; Rinaldi et al., 2024).

Participants

We tested 38 people with misophonia and 76 non-misophonic controls, matched by group according to age ($t(74.30) = 0.70$, $p = .485$, $d = -0.14$) and gender ($X^2 = 0.69$, $p = .709$). The misophonia group comprised 31 females, 3 males, and 4 non-binary participants with a mean age of 20.71 (S.D. =3.96). Our control group comprised 63 females, 8 males, and 5 non-binary participants with a mean age of 20.16 (S.D. =3.97). This matching procedure across age and gender was conducted in advance of the in-person testing session via an online survey monitoring eligibility and demographics. Participants were drawn largely from an undergraduate sample who had been pre-screened using the validated Sussex Misophonia Scale (see below), from which we selected a misophonia group and a control group. We additionally supplemented our misophonic group with four non-students recruited from the Sussex Database of Misophonia Volunteers (also validated using the same measure). The sample size was determined by our pre-registered power analysis (https://osf.io/9g6fs). This required a minimum combined sample of $N = 100$ which is sufficient to reproduce (at power = 0.8, alpha = 0.05) published effect sizes relating to attention alerting ($d = 0.61$, Frank et al., 2019), attention flexibility ($d = 0.51$, Simner et al., 2022), heart rate difference ($d > 0.9$ in both Kumar et al., 2017; Schröder et al., 2019), and skin conductance ($d = 1.14$ in Kumar et al., 2017). Participants were offered either £10 or course credits for research participation. The study was approved by The University of Sussex Science and Technology Research Ethics Committee.

Materials

Sussex misophonia scale (Simner et al., 2024)

The Sussex Misophonia Scale (SMS), is a validated scale which first describes 48 misophonia triggers (e.g., chewing sounds, tapping; Part 1) and then assesses for misophonia phenomenology in a 39-item questionnaire tapping the many social, emotional, and behavioral components (e.g., "I cover my ears to block out certain sounds"; "I don't do well at work because of distractions from sounds," etc.; Part 2). Responses are given on a 5-point scale (Never, Hardly Ever, Sometimes, Often, Always) and total scores run from 0 and 156, with the threshold for misophonia of 51 or higher. The test is available online with automatic scoring at www.misophonia-hub.org/test. This test shows "excellent" classification accuracy (Simner et al., 2024), and also has strong convergent validity, with scores being highly correlated (Smees et al., 2024) with those for the Misophonia Questionnaire (Wu et al., 2014), Duke-Vanderbilt Misophonia Screening Questionnaire (Williams et al., 2022), and AMISO-S (Schröder et al., 2013). The Cronbach's alpha in this sample was 0.97.

Hyperacusis questionnaire (Khalfa et al., 2002)

The Hyperacusis Questionnaire is a 14-item questionnaire measuring symptoms associated with hyperacusis: a sensitivity disorder in which sounds are perceived as uncomfortably loud. Hyperacusis often co-exists with misophonia (Ferrer-Torres & Giménez-Llort, 2022) and items within this scale (e.g., "Do you have trouble concentrating in noisy surroundings?") are responded to on a 4-point scale (No, Yes a little, Yes quite a lot, Yes a lot). Total scores are calculated by summing across items (coded from 1 to 4) with scores therefore falling in the range from 14–56 (where higher scores indicate greater hyperacusis). Cronbach's alpha in this sample was 0.89.

Uncomfortable loudness levels test (British Society of Audiology, 2022)

The Uncomfortable Loudness Level test (ULL) is a more objective test for hyperacusis. Here, sounds are played at increasing volumes until the participant indicates the sound has become uncomfortably loud. People with hyperacusis typically judge sounds to be uncomfortable at a lower loudness than other people (Aazh & Moore, 2017). In our task, participants listened to a maximum of 48 sounds per ear, comprising six different frequencies (250, 500, 1000, 2000, 4000, and 8000 Hz) each at seven increasing decibel-levels per ear (60–90 db, in increments of 5 db). Waveform software (*Waveform Free*, 2024) played the sounds through headphones that canceled any external noise. For each participant, we recorded the highest decibel-level tolerated for each ear at each frequency band (if they reached the maximum of 90 dB without finding it uncomfortable we coded their threshold at 95 dB for the purpose of analysis). Prior to analysis we converted these raw scores into a single value for each participant following Aazh and Moore (2017) by averaging across frequencies and ears. Note that this task is sometimes referred to as loudness discomfort levels or LDL; here we use ULL per recommendation of the British Society of Audiology (British Society of Audiology, 2022).

In-house neurodiversity screener

We asked participants to indicate if they have a diagnosis of either ADHD or autism. In both cases the response options were "yes, I have a formal diagnosis," "No, but I suspect I have [the condition]" or "No, I don't have [the condition]."

Irrelevant distractor task (Forster & Lavie, 2011)

Our attention task contained two parallel components: a task-relevant visual display (from which we obtain behavioral responses) and task-irrelevant auditory presentation (from which we derive the psychophysiological responses). Following Forster and Lavie (2011), the visual display was a 1-second fixation cross followed by 3×3 grid of graphemes (a mixture of letters and numbers; see example in Figure 1). Participants were required to respond to the stimuli in a sequential order (working through each row from left to right and from top row to bottom), categorizing each grapheme as either a letter or a number by key presses. There were 120 arrays generating 1080 behavioral responses (in both accuracy and reaction time, RT), with an additional three practise trials that were excluded from analyses.

The auditory presentation component involved the presentation of 120×10-second intervals, half of which were silent ($n = 60$) and half of which contained a sound ($n = 60$). Of these sounds, 20 were misophonic triggers (e.g., crunch), 20 unpleasant but not misophonic sounds (e.g., ambulance siren), and 20 neutral sounds (e.g., rain). These 120 intervals allowed for 120 psychophysiological responses recorded during the task.[1] The onset of the sound was unpredictable but synchronized to the 2nd, 3rd, 4th or 5th response (out of 9) made to the visual display. In this way we are able to monitor time course of any effects linked to sound onset. We will refer to time course as lag, where the response following sound onset is + 1 and then second grapheme response is + 2, etc. There were additional periods of silence

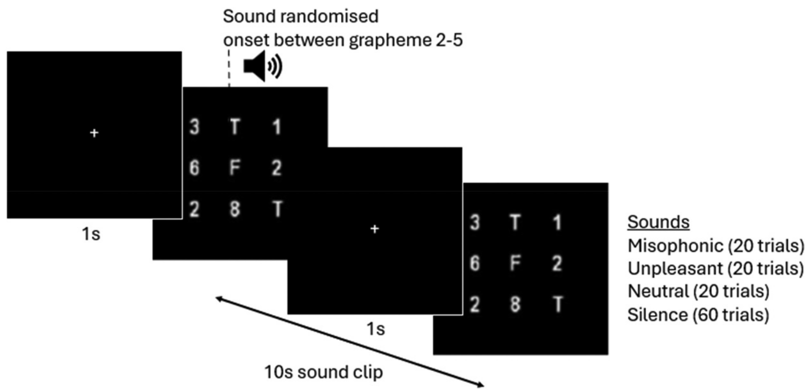

Figure 1. An illustration of the irrelelvant distractor task.

between the 120 × 10-second intervals in which the visual attention task was ongoing. The 10-second silent intervals were important for certain analyses where we needed to match them exactly to the sound intervals (i.e., starting between the 2nd and 5th response) but, from a participant-facing perspective, there was not a perceptible onset linked to the silent interval.

Most sounds were obtained from Hansen et al. (2020) and pre-categorized via their prior ratings from people with misophonia and controls. Two additional unpleasant sounds were taken from Andermane et al. (2023), and one further unpleasant sound was new and did not have ratings available. The discomfort ratings, taken from these previous studies, are shown in Figure 2. They were selected such that neutral sounds are equally rated across both groups, as are unpleasant-non-misophonia sounds; the only difference across groups is for misophonia trigger-sounds. There were 10 different sounds from each category (each repeated twice to give 20 stimuli). The misophonic sounds were: slurping, bite crunching, chewing gum, lip smacks, eating a peach, sipping liquid, slurping, sniffling (two versions), and stirring liquid in a glass. The neutral sounds were: birds, frogs, crows, rolling drawers, bonfire, branch and leaves, crickets, heavy rain, distant thunder, and chuckling. The unpleasant sounds were: mouse squeaking, baby crying, puddle walk, running on concrete, cutlery on glass, sneezing, jackhammer, ambulance, nails on chalkboard, swinging on swingset.

The task was implemented in Psychopy (Peirce, 2007), and the code is available on github: https://github.com/SussexPsychologySoftware/Misophonia-Rinaldi.

Physiological measurements

Physiology was measured using a Biopac MP36 system and Biopac software. Skin conductance was measured with a 2-lead electrodermal activity (EDA) for which disposable Ag-AgCi electrodes with isotonic gel were placed on the first and middle fingers of their non-dominant hand.

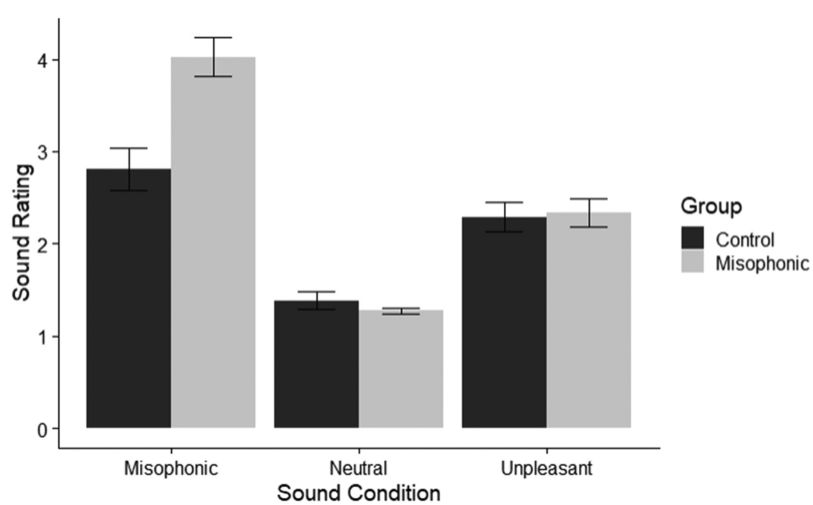

Figure 2. Mean ratings for the sounds on the irrelelvant distractor task showing ratings for misophonics (light gray) and controls (dark gray) across sound conditions (unpleasant, neutral and misophonic). Error bars represent SE.

Electrocardiogram (ECG) was measured with a 3-lead ECG with Ag-AgCi electrodes with dedicated gel were placed on the right collarbone, and underneath the ribs on both sides and a 2-lead EDA. We did not pre-set any filters during physiology acquisition. Markers for when sounds were playing were sent through to the Biopac software from Psychopy through a USB-TTL module. See below for more information on signal processing.

Procedure

Participants first completed a (remote) online survey on their own devices in exchange for course credit (where applicable), which took approximately 20 mins. Here they answered demographic questions (including neurodiversity questions) and then filled out the following measures in the order shown: the SMS (misophonia questionnaire), Hyperacusis Questionnaire, and one final questionnaire to be reported elsewhere.

Participants were then invited to complete our in-person testing, in exchange for either course credit or £10. The in-person session took 1 hour; during this session, participants first completed the ULL (Uncomfortable Loudness Level test) taking approximately 5 minutes. We then set participants up for physiology recordings using a Biopac MP36 system as described above. Participants sat quietly for a 5-minute baseline period and then completed the attentional task during which we recorded both EDA and ECG physiological responses (the attention task took approximately 30 minutes). Lastly participants completed a heart rate tracking task to be reported elsewhere during which only ECG physiological responses were recorded (approx. 10 minutes). The attention task and heart rate tracking tasks were completed on a Windows PC, where participants sat a comfortable distance (around 60 cm) away from the 24-inch monitor display (such that the viewing angle of the 3 × 3 array was approximately 14 degrees). A secondary monitor was also connected for researchers to set up and monitor physiology, this was turned away from the participant. Participants wore noise canceling headphones throughout the task with audio set at max volume.

Physiological signal processing

We processed the raw physiological data in Python (version 3.12.1) using the Neurokit2 package (Makowski et al., 2021). We began by removing practise trial data.

We processed heart rate data by creating epochs around the 10-second sound intervals (including the matched 10-second silent intervals), with prior research suggesting this to be a minimal duration for extracting these measures (Kirk et al., 2022). We then calculated time-domain heart rate variability indices, again using Neurokit2. We removed one individual from the heart rate analyses due to a fault with their heart rate collection.

For skin conductance we set up 15 second epochs again starting from sound onset (or the equivalent for silent intervals). We then computed event-related EDA metrics including our main dependent variables peak amplitude response, and peak amplitude response time. We identified 16 individuals (14% of participants) as non-responders as they had skin conductance responses to less than 20% of sound trials. They were removed from the EDA analyses but retained elsewhere. This exclusion criterion was part of our pre-registered protocol and the proportion of non-responders is in line with expectation (e.g., Biopac Systems, 2025).

Analytic plan

Following our pre-registration, we use separate analyses to examine our behavioral findings (i.e., RT and accuracy from the attention task) and physiological findings (i.e., heart rate, heart rate variability, and skin conductance responses during the attention task). In both cases, we have a mixed linear model contrasting group (2 levels, between subjects) and sound condition (4 levels, within subjects), with ULL entered as a covariate. Planned follow-up analyses of the behavioral data adds lag (1 to 4 trials following sound onset; following Forster & Lavie, 2011) as a further variable to determine the time-course of attention differences. Across all reaction time analyses we restricted the data to only include correct trials. As described above we used the SMS threshold (≥51) to split participants into our groups of people with and without misophonia. Our pre-registration anticipated two further exclusion criteria based on data being substantially missing (<50% of trials attempted) or inaccurate (<70% correct overall) but, in practice, no participant met either criterion.

Across all analyses we first ran assumptions of normality, linearity and homogeneity of variance. Where violations of assumptions were found we obtain robust parameters. We also report effect sizes throughout using Cohen's d and eta squared. Post-hoc tests are corrected for multiple comparisons (using Tukey's method). Other measure specific protocols are mentioned in the relevant sections below. All analyses described below were conducted in R (R version 4.1.3) and the following packages: afex v. 1.3.1, BayesFactor v. 0.9.12.4.4, car v. 3.1.2, cowplot v. 1.1.1, emmeans v. 1.7.3, Hmisc v. 5.0.1 knitr v. 1.39, tidyverse v. 2.0.0 vroom v. 1.6.1.

Results

Behavioral analyses

Group characteristics

Although not part of our inclusion/exclusion criteria, participants were asked about the presence of other conditions to determine potential confounds and permit exploratory analyses. These are summarized in Table 1. There were significant differences in self-reported autism prevalence ($\chi2 = 14.55$, $p < .001$) and self-reported ADHD prevalence ($\chi2 = 10.76$, $p = .005$) in the misophonic group (See Table 1). These were not incorporated into our pre-registered analysis plan as they are tangential to our research questions, but we now consider them in exploratory analyses (see Supplementary Materials). We confirm here that there were no significant main effects nor any significant interactions involving the presence of ADHD/autism (combining suspected and diagnosed groups), and the inclusion of ADHD or autism as a variable did not eliminate significant effects linked to misophonia documented below.

In terms of hyperacusis, we found a significantly higher proportion of self-reported hyperacusis using the HQ for the misophonic group ($M = 24.47$, SD = 7.61) compared to controls ($M = 14.35$, SD = 6.40; $t(50.87) = 6.58$, $p = <.001$, $d = -1.49$[very large]). However, since many items in this scale are also relevant to misophonia (Smees et al., 2024) we also considered objective values from the ULL (Uncomfortable Loudness Levels test) where we found no significant group differences. Loudness tolerance was no different for people with misophonia ($M = 77.71$ dB, SD = 9.41) compared to controls ($M = 80.06$ dB, SD = 9.37; $t(73.86) = 1.26$, $p = .213$, $d = 0.25$[small]). We entered the ULL score as a covariate in all analyses as a proxy measure of loudness hyperacusis as part of our pre-registered analysis plan, and report below where ULL is significant (see Supplementary Materials for all analysis tables which include full ULL results).

Reaction time

Examining differences between groups and sound condition

We first looked at group-wise differences between the misophonia group and controls in a 2 × 4 ANCOVA crossing Group (Misophonia, Control) and Sounds (Silent, Misophonic, Neutral, Unpleasant), where ULL score was entered as the covariate. Results are illustrated in Figure 3. There was no main effect of group (F (1,103) = 0.49, $p = .486$, $\eta2\ G = .004$) comparing the overall RT in seconds of people with misophonia ($M = 0.48$, SD = 0.87) and controls ($M = 0.46$, SD = 0.85). There was a significant main effect of sound condition (F (2.73, 281.64) = 42.57, $p < .001$, $\eta2\ G = .026$[small]). The main effect of condition was explored using post hoc paired t-tests within groups. These showed significant effects of

Table 1. Descriptive information on each group.

Misophonia Group	Mean Age (SD)	Mean Hyperacusis Score (SD)	Mean ULL Score (SD)	Percentage formal or suspected Autism	Percentage formal or suspected ADHD
Misophonic	20.71 (3.96)	24.47 (7.61)	77.71 (9.41)	42.10%	36.84%
Control	20.16 (3.97)	14.35 (6.40)	80.06 (9.37)	10.53%	15.79%

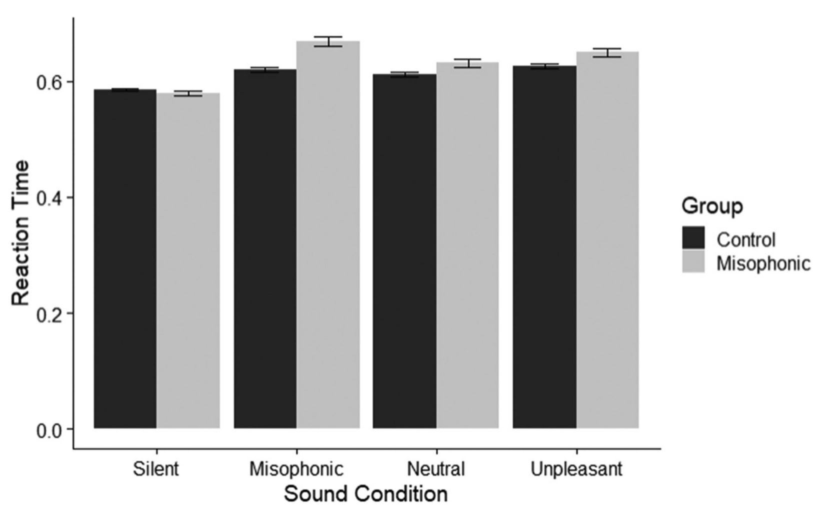

Figure 3. Reaction times (s) on the irrelevant distractor attention task for misophonics (light gray) and controls (dark gray) across sound conditions (unpleasant, silent, neutral and misophonic). Error bars represent SE.

sound-based distraction ($p < .001$) for all comparisons (misophonic sounds v. silence, neutral sounds v. silence, unpleasant sounds v. silence) for both misophonic and control groups. There was also a significant main effect of ULL (F (1,103) = 4.06, $p = .047$, $\eta 2\ G = .036$[small]; see below), and a significant interaction between group and sound condition (F (2.73, 281.64) = 7.12, $p < .001$, $\eta 2\ G = .004$[small]).

The interaction between group and sound condition was explored by considering distractor costs (i.e., differences in RT relative to silence). This, in effect, is a measure of distraction relative to the baseline speed of responding in non-distracting conditions. Here a main effect of group is now found (F (1, 103) = 12.50, $p < .001$, $\eta 2\ G = .080$[small]) with misophonia linked to a greater overall distraction to sounds. Importantly, the interaction between group and condition is still significant (F (1.99, 204.88) = 3.75, $p = .025$, $\eta 2\ G = .010$[small]) showing that some types of sound are more distracting to people with misophonia than others. The biggest group difference was for misophonic trigger sounds (see Figure S1 in Supplementary Materials), as initially hypothesized.

The main effect of ULL manifests itself as an overall slowing of response times for people with less tolerance for loud sounds; this was true both in the sound trials (correlation between ULL and RT being $r = -0.20$, $p = .041$, collapsing across all three sounds) and a similar effect size in silent trials, perhaps due to the anticipatory nature of the task where sounds are unpredictable, but this did not reach significance (correlation between ULL and RT being $r = -0.18$, $p = .060$).

Examining the time course of distraction

We next re-ran the analysis as above but added in lag. We define lag as the number of grapheme-responses given after the onset of the sound has been triggered by a keypress (to a grapheme in positions 2 to 5 of the array) taking into account the next four responses (i.e., +1, +2, +3, +4 graphemes, etc). For example, if a sound (or an equivalent silent interval) is trigged by a keypress to the third grapheme then we examine performance on the fourth (+1) to seventh (+4) grapheme. Figure 4 shows that performance on the task slows down soon after sound onset (peaking at the +2 lag) and then returns to normal, i.e., a profile of distraction followed by re-engagement. The same pattern is found in both groups but is larger in the misophonic group. This manifests statistically as a significant main effect of lag (F (2.33, 239.69) = 6.03, $p = .002$, $\eta 2\ G = .006$[small]), and a significant interaction between group and lag (F (2.33, 239.69) = 4.20, $p = .012$, $\eta 2\ G = .004$[small]), in addition to the significant interaction between group and sound condition explored above. All other comparisons were not significant. Post-hoc t-tests to explore the group ×lag interaction did not reveal significant differences between groups overall (misophonia, control): lag +1 $p = .773$, lag +2 $p = .068$, lag +3 $p = .215$, lag +4 $p = .464$. But significant between-group differences *were* found at the +2 lag when considering sound trials ($p = .042$) separately from silent trials ($p = .668$). That is, people with misophonia are more distracted by sounds and, at least in terms of RT, the distraction effects are more pronounced soon after the onset.

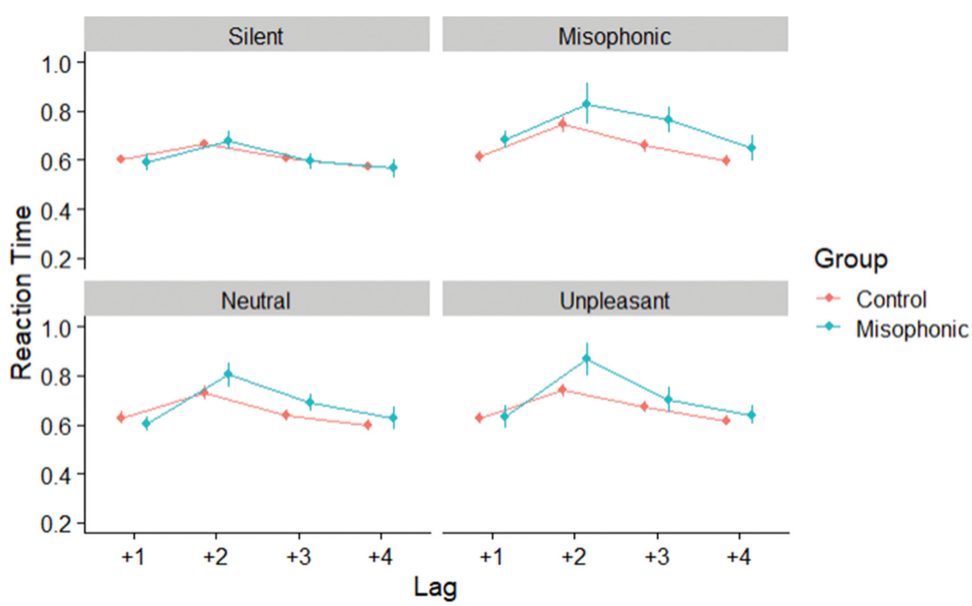

Figure 4. Reaction times (s) on the irrelevant distractor attention task for misophonics (blue) and controls (red) across lag onsets where panels show different sound conditions (unpleasant, silent, neutral and misophonic).

Accuracy

Examining differences between groups and sound condition

We next looked at accuracy as measured by percentage correct. We again looked at group-wise differences in a 2 (Misophonia, Control groups) ×4 (Silent, Misophonic, Neutral, Unpleasant sounds) ANCOVA where ULL score was again entered as the covariate. These results are illustrated in Figure 5. The data is significantly skewed toward ceiling reflecting a high degree of accuracy on the task. We therefore report robust parameters for the resulting ANCOVA model (see Supplamentary Materials). There was a significant main effect of group ($F(1,103) = 5.45$, $p = .021$, $\eta p^2 = .05$[small]) where people with misophonia ($M = 96.18\%$ correct, SD = 3.83) were less accurate than controls ($M = 97.36\%$, SD = 2.07). We found no main effect of sound condition ($F(2.87,295.21) = 0.48$, $p = .689$, $\eta p^2 = .005$[small]), nor ULL ($F(1,103) = 0.36$, $p = .551$, $\eta p^2 = .003$[small]), but there was a significant interaction between group and condition ($F(2.87,295.21) = 2.85$, $p = .041$, $\eta p^2 = .03$[small]).

We examined post-hoc contrasts of the significant interaction between group and sound condition. There was a significant difference across misophonic sounds (t (102) = 2.96, $p = .004$, $d = 0.63$[large]) where people with misophonia ($M = 95.59\%$, SD = 4.93) scored significantly lower than controls ($M = 97.58\%$, SD = 1.97), and there was a significant effect for neutral sounds (t (102) = 2.24, $p = .003$, $d = 0.49$[medium]) where again the misophonic group scored lower ($M = 96.33\%$, SD = 3.38) than controls ($M = 97.58\%$, SD = 2.14). There was no significant difference between groups for either unpleasant (t (102) = 1.22, $p = .223$, $d = 0.26$[small]), or silent trials (t (102) = 1.65, $p = .103$, $d = 0.33$[medium]). As before, we also conducted a post hoc analysis of distractor cost (distractor-sound minus silence baseline) to determine if the interaction remained, and this was the case for errors as for response times ($F(1.97, 202.77) = 3.25$, $p = .042$, $\eta p^2 = .03$[small]). This was driven by a significant group difference for misophonic trigger sounds (t (102) = 2.35, $p = .021$, $d = 0.51$[medium]) where misophonic participants were more distracted by misophonic sounds than controls, with controls having a positive score (i.e., more accurate at misophonic trials than silent trials) and misophonic participants having a negative score (i.e., reflecting lower accuracy at misophonic trials than silent trials). There were no other significant group differences for the other sounds (see Figure S2 in Supplementary Materials for figure depicting this).

Examining the time course of distraction

We again re-ran the analysis as above but added in lag as the number of grapheme-responses given after the onset of the sound (i.e., onset of sound +1, +2, +3, +4 graphemes; See Figure 6). We found a significant main effect of lag (F (2.52, 259.32) = 23.44, $p < .001$, $\eta p^2 = .19$[medium]). All other comparisons were not significant. Exploring the main effect of lag further we found estimated marginal accuracy means decreased with lag (onset +1 M = 97.91, onset +2 M = 96.67, onset +3 M = 96.32, onset +4 M = 95.94). There were significant differences between onset +1 and all other lags ($p < .001$), as well as a significant difference between onset +2 and +4 ($p = .046$) but no significant differences between onset +2 and +3 ($p = .412$) or between onset +3 and +4 ($p = .256$). The interactions were not explored further due to non-significance.

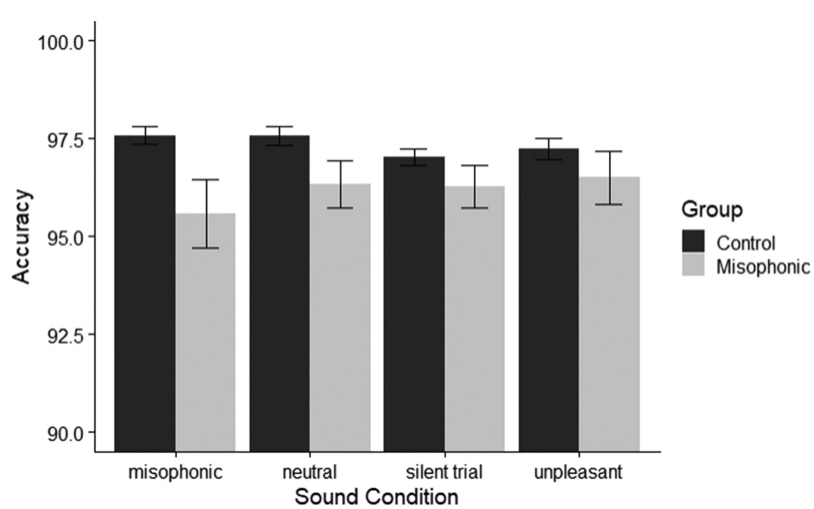

Figure 5. Accuracy (% correct) on the irrelevant distractor attention task for misophonics (light gray) and controls (dark gray) across sound conditions (silent, misophonic, neutral and unpleasant). Error bars represent SE.

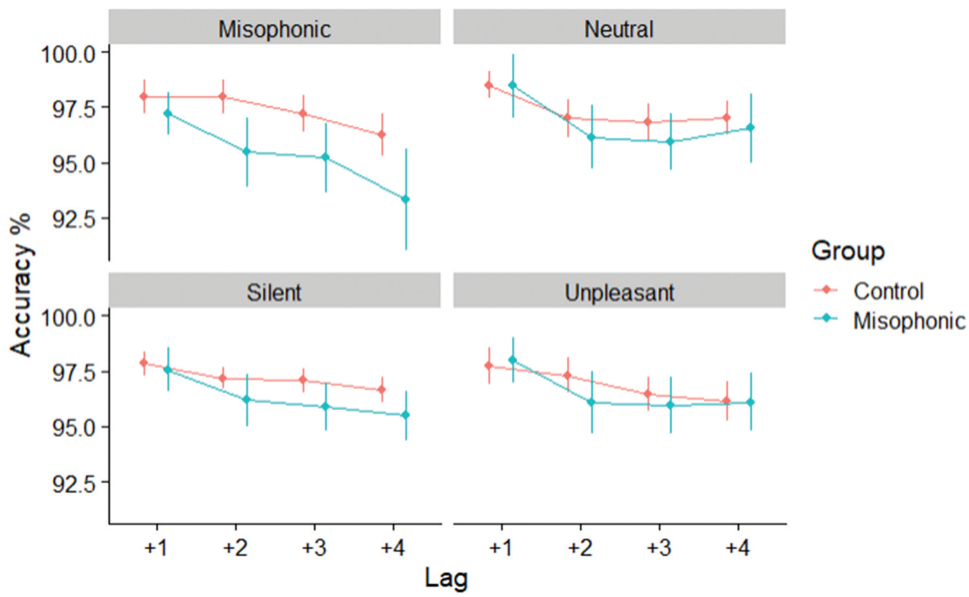

Figure 6. Accuracy (% correct) by lag from onset on the irrelevant distractor attention task for misophonics (blue) and controls (red) where panels show different sound conditions.

Physiological analyses

Skin conductance

Skin conductance response. We looked at skin conductance responses during the irrelevant distractor task. We again looked at group-wise differences between misophonia and controls in a 2×4 ANCOVA crossing group (Misophonia, Control) and sound (Misophonic, Neutral, Unpleasant, Silent) where ULL score was entered as the covariate. These results are illustrated in Figure 7. The residuals were not normally distributed so we again report robust parameters for the resulting ANCOVA model. There was no main effect of group (F (1,95) = 0.44, $p = .510$, $\eta p^2 = .005$[small]), no main effect of condition (F (2.66,252.78) = 0.61, $p = .589$, $\eta p^2 = .001$[small]) and no interaction between group and condition (F (2.66,252.78) = 2.23, $p = .093$, $\eta p^2 = .02$[small]). Bayes factors for sound condition and for the interaction were both less than 0.33 suggesting evidence to support the null hypothesis (Condition $BF_{10} = 0.01$, Interaction $BF_{10} = 0.04$). Bayes Factor for group was just above a third suggesting insufficient evidence (Group $BF_{10} = 0.37$).

Skin conductance response time. We next looked at skin conductance time to reach the peak amplitude,

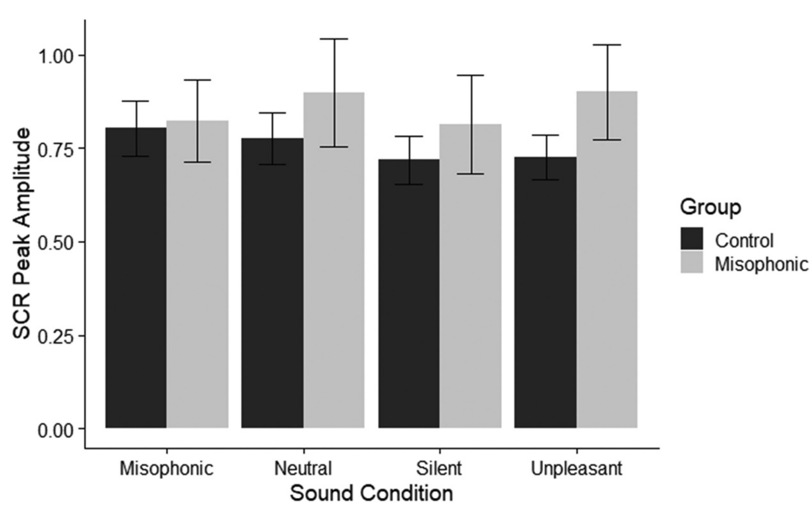

Figure 7. Peak amplitude skin conductance responses for misophonics (light gray) and controls (dark gray) across sound conditions. Error bars represent SE.

again using a 2 (Misophonia, Control groups) ×4 (Misophonic, Neutral, Unpleasant, Silent) ANCOVA where ULL score was entered as the covariate and again reporting robust parameters for the resulting ANCOVA model (See Figure 8). There was no main effect of group (F (1,95) = 0.42, p = .519, ηp^2 = .004-[small]), no main effect of condition (F (2.74, 260.04) = 1.25, p = .293, ηp^2 = .01[small]) and no interaction between group and condition (F (2.74, 260.04) = 2.19, p = .096, ηp^2 = .02[small]). Bayes factors for Group and Interaction were less than 0.33 suggesting evidence to support the null hypothesis (Group BF_{10} = 0.13, Interaction BF_{10} = 0.05). The Bayes factor for Condition was < 3 suggesting evidence to reject the null. This likely reflects a difference between silent and sound trials as without including the silent condition the Bayes factor was less than 0.33 (Condition BF_{10} = 0.07). The slower time to reach "peak" for silent trials likely reflects noise in the data (noting that a mean value of 7.5s would be expected if sampling from a uniform distribution of 15s in duration).

ECG data

Heart rate. We looked at heart rate beats per minute (BPM) during the irrelevant distractor task, using a 2 × 4 ANCOVA crossing group (Misophonia, Control) and sound (Misophonic, Neutral, Unpleasant, Silent) with ULL as the covariate (See Figure 9). There was a significant main effect of group (F (1,94) = 8.8, p = .004, ηp^2 = .09[small]) where misophonic participants had a higher (M = 86.66, SD = 10.46) heart rate than controls (M = 80.26, SD = 10.79), but no main effect of condition (F (2.82, 264.95) = 0.10, p = .951, ηp^2 = .001[small]) and no interaction between group and condition (F (2.82, 264.95) = 0.56, p = .628, ηp^2 = .006[small]). That is, people with misophonia had a higher heart rate regardless of sound condition.

Heart rate variability. We finally looked at heart rate variability (HRV) using the RMSSD index across the irrelevant distractor task, again using the same type of 2 × 4 ANCOVA as before (i.e., crossing group with sound, using ULL as the covariate; See Figure 10). There was a significant main effect of group (F (1,99) = 5.01, p = .027, ηp^2 = .05[small]) where people with misophonia (M = 29.76, SD = 23.42) had significantly lower HRV compared to controls (M = 38.04, SD = 30.13). There was no main effect of condition (F(2.54,251.36) = 1.18, p = .315, ηp^2 = .01[small]), and there was no interaction between group and condition ((2.54,251.36) = 0.18, p = .882, ηp^2 = .002[small]).

Discussion

The aim of this study was to elucidate the role of attention in misophonia. We hypothesized that misophonic trigger sounds may be potent distractors (to those with misophonia) because of the high salience they are afforded including, but not necessarily limited to, a strong autonomic arousal response to those sounds. However, it is also conceivable that people with misophonia have trait-level individual differences in their attentional abilities that may themselves act as predisposing influences in the onset of misophonia (i.e., to ignore or down-regulate responses to nuisance stimuli). This is consistent with research (both questionnaires and performance measures) showing differences in attention across a wide range of stimuli (including

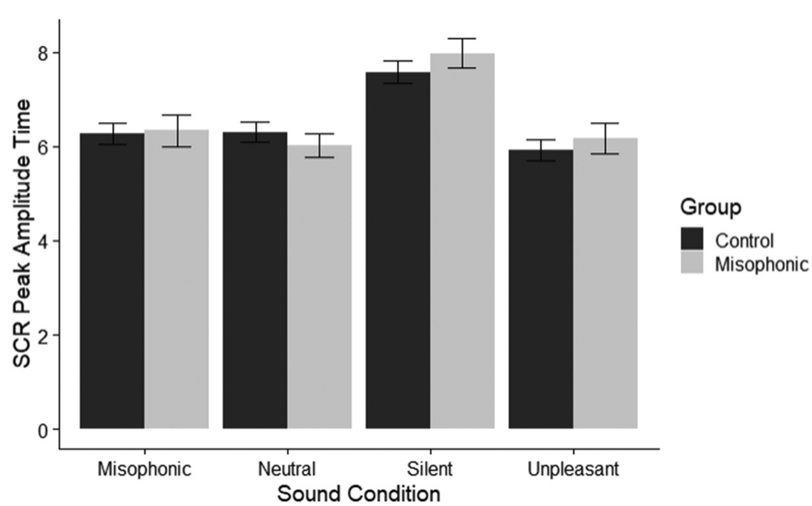

Figure 8. Peak amplitude skin conductance time for misophonics (light gray) and controls (dark gray) across sound conditions. Error bars represent SE.

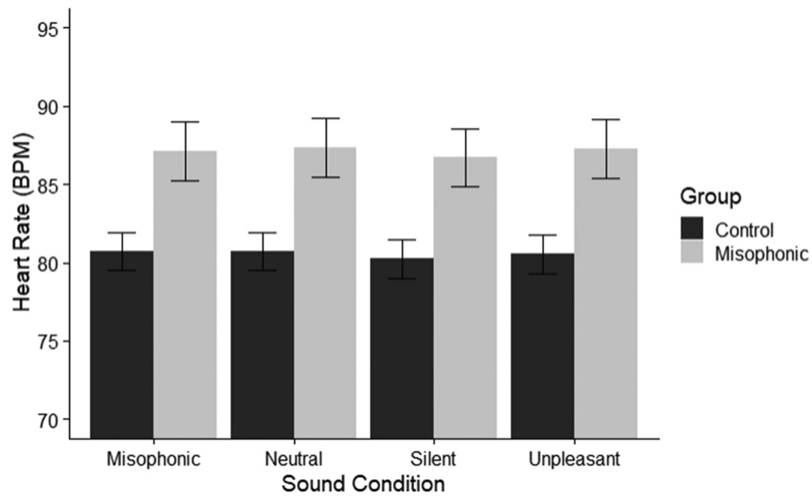

Figure 9. Heart rate (BPM) for misophonics (light gray) and controls (dark gray) across sound conditions. Error bars represent SE.

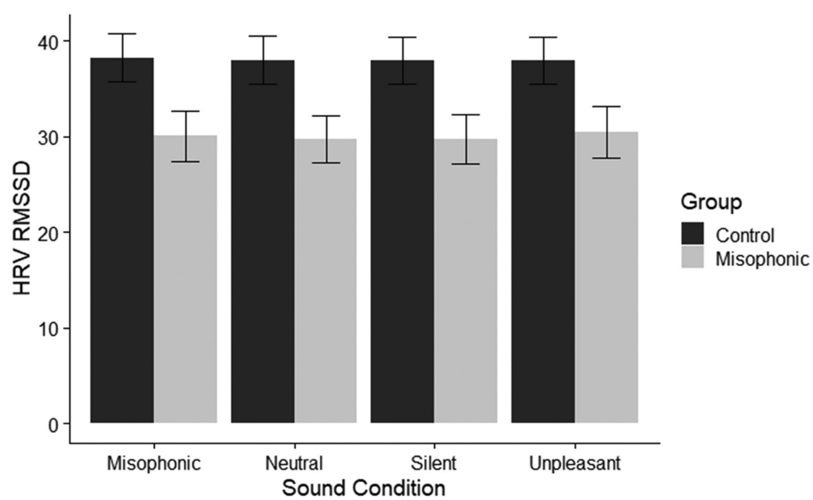

Figure 10. Heart rate variability for misophonics (light gray) and controls (dark gray) across sound conditions. Error bars show SE.

those not directly linked to misophonia). The strength of the present research is that we adapted an ecologically valid paradigm (Irrelevant Distractor Task; Forster & Lavie, 2011) that enables us to contrast different stimuli (three different kinds of sounds) across time (e.g., different lags from sound onset) in different dependent variables (psychophysiological, behavioral). We find evidence that misophonic triggers are more potent distractors than other sounds (in people with misophonia) in terms of reduced behavioral performance (slower and less accurate responses to visual targets). However, this sits against a backdrop of more pervasive differences in distractibility found for all sounds (compared to silence) together with traits like differences in heart-rate and heart-rate variability found across all conditions in the task (sounds and silence). In sum, this points to multiple differences in attentional mechanisms in misophonia.

Considering the psychophysiological findings first, there is a general consensus in the literature that people with misophonia experience greater autonomic arousal (heart rate, electrodermal response) for trigger sounds relative to control participants. However, this literature has invariably presented sounds as task-relevant and/or in the absence of any stimulus competition. The extent to which this also occurs when sounds are task-irrelevant was addressed in the current research. We did not find significant differences in skin conductance measures (timing or amplitude of the peak response), and the observed group-wise cardiac (ECG) differences were pervasive across the task. We didn't find any effect of sound condition or any interaction between groups and sound condition in ECG. This makes it implausible that trial-by-trial variation in autonomic arousal is driving the observed behavioral distraction effects (where there are significant differences between sound versus silence, and misophonic triggers versus other sounds). A more likely explanation is that attentional capture is driven by perceptual processing and identification of sounds rather than a more sluggish embodied salience response. This conclusion is supported by our analysis of the time-course of distraction which occurs soon after sound onset and quickly resolves.

Whereas increases in heart rate are considered as a marker of arousal (driven by the sympathetic nervous system), heart-rate variability, HRV, is linked to the regulation of that arousal (and is driven by interactions between sympathetic and parasympathetic nervous systems where the latter exerts a braking mechanism). Low HRV, i.e., a more regular and rhythmic heart rate, is linked to poorer autonomic control and has more generally been linked to low emotion regulation. Within the context of misophonia, it is possible that there are multiple interacting traits differences (e.g., poor emotion regulation, difficulties in ignoring irrelevant perceptual stimuli) that conspire in its etiology. Our study is consistent with this view. This stands in contrast to alternative models of misophonia, such as conditioned reflexes/responses, which places the primary focus on learning mechanisms (Dozier & Morrison, 2017; Dozier et al., 2017) rather than individual differences in domains such as emotion, perception, or attention. The extent to which misophonia is related to hot versus cold cognitive processes (i.e., those with and without an emotional content) remains debated, and our research suggests that both are affected (see also Black et al., 2026).

One strength of our study is that we can disentangle effects of misophonia from that of loudness hyperacusis (measured by Uncomfortable Loudness Levels) and certain other comorbidities (diagnosed autism and/or ADHD). Our pre-registered analysis plan was to consider ULL as a covariate. Whereas misophonia was linked to widespread differences on multiple measures (accuracy, response time, ECG) there was only a single result linked to ULL; namely, a main effect on response times: loudness hyperacusis (i.e., lower ULL) is linked to slower response times. This did not interact with condition (in contrast to the group X condition interaction for misophonia), suggesting that it reflects a hypervigilance for sounds during the visuo-motor task. In contrast, the pattern for misophonia is best described as a brief orienting response to sound onsets that results in a more specific detriment in performance (greater for some sounds than others, greater at some lags than others). Future research should rule-out other potential comorbidities such as anxiety and obsessive-compulsive tendencies.

In terms of limitations of the research, we do not have a full account of the null result for the skin conductance response. Our speculation is that this is due to our attention manipulation, but this would require further research to test this directly (e.g., comparing the same sounds under different attentional demands within the same participants). The alternative explanation is that these effects, reported by others, are weaker or more variable in nature. The current study is the first step toward exploring attention mechanisms in misophonia, in a more realistic environment in which the misophonic sounds are task irrelevant. It would be important to replicate the findings in an independent sample, noting the limitation that the present study tests several hypotheses with multiple dependent variables (possibly leading to Type I errors). Replication is considered preferable to an experiment-wide correction across all observed *p*-values which would be overly conservative, inflating Type II error rates. We also used uncomfortable loudness level tests as an objective proxy for loudness-based hyperacusis but replicating the pattern of results in a sample with formal clinician-diagnoses of misophonia and/or hyperacusis is an important future step. Our study also used dual methods of incentivizing (money vs course credit) and whilst this was equivalent across misophonic and control groups, this is another potential factor that could be eliminated in future studies. Our study also does not enable us to know whether people with misophonia have greater distractibility per se or whether this occurs mainly/solely for sounds. Previous research using the Irrelevant Distractor Task has used peripheral visual stimuli as distractors (e.g., images of cartoon characters, or emotional images) (Grimshaw et al., 2018). It would be important to establish whether group differences in distraction are found here too or, indeed, are still found for neutral sounds when triggers are completely absent. Further research should clarify whether this generalized enhanced auditory distraction is found in all contexts, or only in contexts within which the trigger sounds might be expected (e.g., mealtimes). Finally, whilst the design of our study mirrors that of others in the literature (by comparing a relatively small number of misophonic triggers, unpleasant sounds, neutral sounds) this is a broadbrush approach that does not enable us to link our data to idiosyncratic differences in the aversiveness of stimuli between people. Further, we have here considered common co-morbidities such as hyperacusis, autism and ADHD which have known sensory and attentional impacts, but there are other common co-morbidities in misophonia such as OCD, which have less clear attentional links, which are yet to be explored.

To summarize, we provide evidence of increased auditory distraction among people with misophonia. This applied to all three kinds of sounds used in this study, but was greatest for misophonic trigger sounds (e.g., chewing). In addition, we show group differences in arousal (heart rate) and its regulation (heart rate variability) during the task. The different nature of the behavioral and psychophysiological findings in our study supports the existence of separate mechanisms in the etiology of misophonia: one relating to attentional engagement, and one relating to emotion/physiological regulation.

Note

1. Due to a technical error 10 subjects had less than 120 trials (between 115–119) and 5 had more than 120 trials (between 121 and 124 trials).

Acknowledgments

Many thanks to Max Lovell for his assistance with task coding and Biopac set up.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Authors LJ Rinaldi, R Agbude, J Simner, and J Ward received funding from the Misophonia Research Fund via a grant awarded to J Ward.

Data availability statement

Anonymised data and analysis code are deposited on the OSF https://osf.io/bh3dc/overview.

References

Aazh, H., & Moore, B. C. J. (2017). Factors related to uncomfortable loudness levels for patients seen in a tinnitus and hyperacusis clinic. *International Journal of Audiology*, *56*(10), 793–800. https://doi.org/10.1080/14992027.2017.1335888

Abramovitch, A., Herrera, T. A., & Etherton, J. L. (2024). A neuropsychological study of misophonia. *Journal of Behavior Therapy and Experimental Psychiatry*, *82*, 101897. https://doi.org/10.1016/j.jbtep.2023.101897

Andermane, N., Bauer, M., Sohoglu, E., Simner, J., & Ward, J. (2023). A phenomenological cartography of misophonia and other forms of sound intolerance. *Iscience*, *26*(4). https://doi.org/10.1016/j.isci.2023.106299

Biopac Systems. (2025). *Introduction to EDA*. https://www.biopac.com/wp-content/uploads/EDA-Guide.pdf

Black, V. K., Allen, K. J. D., Aazh, H., Johnson, S. L., & Erfanian, M. (2026). Misophonia symptom severity is linked to impaired flexibility and heightened rumination. *British Journal of Psychology*, *117*(1), 271–300. https://doi.org/10.1111/bjop.70025

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry*, *16*(1), 5–13. https://doi.org/10.1002/wps.20375

British Society of Audiology. (2022). Recommended procedure: Determination of uncomfortable loudness levels. https://www.thebsa.org.uk/wp-content/uploads/2023/10/OD104-36-Recommeded-Procedure-Unconfortable-Loudness-2.pdf

Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology*, *62*(1), 73–101. https://doi.org/10.1146/annurev.psych.093008.100427

Dozier, T. H., Lopez, M., & Pearson, C. (2017). Proposed diagnostic criteria for misophonia: A multisensory conditioned aversive reflex disorder. *Frontiers in Psychology*, *8*(NOV), 284398. https://doi.org/10.3389/fpsyg.2017.01975

Dozier, T. H., & Morrison, K. L. (2017). Phenomenology of misophonia: Initial physical and emotional responses. *American Journal of Psychology*, *130*(4), 431–438. https://doi.org/10.5406/AMERJPSYC.130.4.0431

Edelstein, M., Brang, D., Rouw, R., & Ramachandran, V. S. (2013). Misophonia: Physiological investigations and case descriptions. *Frontiers in Human Neuroscience*, *7*(296). https://doi.org/10.3389/fnhum.2013.00296

Ferrer-Torres, A., & Giménez-Llort, L. (2021). Sounds of silence in times of COVID-19: Distress and loss of cardiac coherence in people with misophonia caused by real, imagined or evoked triggering sounds. *Frontiers in Psychiatry*, *12*, 638949. https://doi.org/10.3389/fpsyt.2021.638949

Ferrer-Torres, A., & Giménez-Llort, L. (2022). Misophonia: A systematic review of current and future trends in this emerging clinical field. *International Journal of Environmental Research and Public Health*, *19*(11), 6790. https://doi.org/10.3390/IJERPH19116790

Forster, S., & Lavie, N. (2011). Entirely irrelevant distractors can capture and captivate attention. *Psychonomic Bulletin and Review*, *18*(6), 1064–1070. https://doi.org/10.3758/s13423-011-0172-z

Frank, B., Roszyk, M., Hurley, L., Drejaj, L., & McKay, D. (2019). Inattention in misophonia: Difficulties achieving and maintaining alertness. *Journal of Clinical and Experimental Neuropsychology*, *42*(1), 1–10. https://doi.org/10.1080/13803395.2019.1666801

Geisler, F. C. M., Vennewald, N., Kubiak, T., & Weber, H. (2010). The impact of heart rate variability on subjective well-being is mediated by emotion regulation. *Personality & Individual Differences*, *49*(7), 723–728. https://doi.org/10.1016/J.PAID.2010.06.015

Ghorbani, S., Asadi, D. D. M., Ashouri, A., Farahani, H., Saneh, N. A., & Abedi, Z. (2023). The mediating role of sensory processing and attentional control in the relationship between misophonia and severity of disability, emotional traits, and disgust propensity in Iranian college students. *Authorea Preprints*. https://doi.org/10.22541/AU.168802206.60400270/V1

Grimshaw, G. M., Kranz, L. S., Carmel, D., Moody, R. E., & Devue, C. (2018). Contrasting reactive and proactive control of emotional distraction. *Emotion (Washington, DC)*, *18*(1), 26–38. https://doi.org/10.1037/EMO0000337

Grossini, E., Stecco, A., Gramaglia, C., De Zanet, D., Cantello, R., Gori, B., Negroni, D., Azzolina, D., Ferrante, D., Feggi, A., Carriero, A., & Zeppegno, P. (2022). Misophonia: Analysis of the neuroanatomic patterns at the basis of psychiatric symptoms and changes of the orthosympathetic/parasympathetic balance. *Frontiers in Neuroscience*, *16*, 827998. https://doi.org/10.3389/fnins.2022.827998

Hansen, H. A., Leber, A. B., & Saygin, Z. M. (2020). What sound sources trigger misophonia? Not just chewing and breathing. *Journal of Clinical Psychology*, *77*(11), 2609–2625. https://doi.org/10.1002/jclp.23196

Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., & Wang, P. (2010). Research domain criteria (RDoC): Toward a new classification framework for research on mental disorders. *American Journal of Psychiatry*, *167*(7), 748–751. https://doi.org/10.1176/appi.ajp.2010.09091379

Jastreboff, P. J., & Jastreboff, M. M. (2023). The neurophysiological approach to misophonia: Theory and treatment. *Frontiers in Neuroscience*, *17*, 895574. https://doi.org/10.3389/fnins.2023.895574

Khalfa, S., Dubal, S., Veuillet, E., Perez-Diaz, F., Jouvent, R., & Collet, L. (2002). Psychometric normalization of a hyperacusis questionnaire. *ORL*, *64*(6), 436–442. https://doi.org/10.1159/000067570

Kim, H. G., Cheon, E. J., Bai, D. S., Lee, Y. H., & Koo, B. H. (2018). Stress and heart rate variability: A meta-analysis and review of the literature. *Psychiatry Investigation*, *15*(3), 235. https://doi.org/10.30773/PI.2017.08.17

Kirk, P. A., Bryan, A. D., Garfinkel, S. N., & Robinson, O. J. (2022). RapidHRV: An open-source toolbox for extracting heart rate and heart rate variability. *PeerJ*, *10*, e13147. https://doi.org/10.7717/peerj.13147

Kumar, S., Tansley-Hancock, O., Sedley, W., Winston, J. S., Callaghan, M. F., Allen, M., Cope, T. E., Gander, P. E., Bamiou, D. E., & Griffiths, T. D. (2017). The brain basis for misophonia. *Current Biology*, *27*(4), 527–533. https://doi.org/10.1016/j.cub.2016.12.048

Makowski, D., Pham, T., Lau, Z. J., Brammer, J. C., Lespinasse, F., Pham, H., & Chen, S. A. (2021). NeuroKit2: A python toolbox for neurophysiological signal processing. *Behavior Research Methods*, *53*(4), 1689–1696. https://doi.org/10.3758/s13428-020-01516-y

Namkung, H., Kim, S. H., & Sawa, A. (2017). The insula: An underestimated brain area in clinical neuroscience, psychiatry, and neurology. *Trends in Neurosciences*, *40*(4), 200. https://doi.org/10.1016/J.TINS.2017.02.002

Peirce, J. W. (2007). Psychopy-psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1–2), 8–13. https://doi.org/10.1016/J.JNEUMETH.2006.11.017

Reynard, A., Gevirtz, R., Berlow, R., Brown, M., & Boutelle, K. (2011). Heart rate variability as a marker of self-regulation. *Applied Psychophysiology and Biofeedback*, *36*(3), 209–215. https://doi.org/10.1007/s10484-011-9162-1

Rinaldi, L. J., Agbude, R., Makowski, D., Forster, S., Lovell, M., Simner, J., & Ward, J. (2024). Attentional distraction and physiological arousal in misophonia. https://doi.org/10.17605/OSF.IO/9G6FS

Schröder, A., van Wingen, G., Eijsker, N., San Giorgi, R., Vulink, N. C., Turbyne, C., & Denys, D. (2019). Misophonia is associated with altered brain activity in the auditory cortex and salience network. *Scientific Reports*, *9*(1), 1–9. https://doi.org/10.1038/s41598-019-44084-8

Schröder, A., Vulink, N., & Denys, D. (2013). Misophonia: Diagnostic criteria for a new psychiatric disorder. *PLOS ONE*, *8*(1), e54706. https://doi.org/10.1371/journal.pone.0054706

Segerstrom, S. C., & Nes, L. S. (2007). Heart rate variability reflects self-regulatory strength, effort, and fatigue. *Psychological Science*, *18*(3), 275–281. https://doi.org/10.1111/j.1467-9280.2007.01888.x

Siepsiak, M., Vrana, S. R., Rynkiewicz, A., Rosenthal, M. Z., & Dragan, W. Ł. (2023). Does context matter in misophonia? A multi-method experimental investigation. *Frontiers in Neuroscience*, *16*, 880853. https://doi.org/10.3389/fnins.2022.880853

Silva, F. E. D., & Sanchez, T. G. (2019). Evaluation of selective attention in patients with misophonia. *Brazilian Journal of Otorhinolaryngology*, *85*(3), 303–309. https://doi.org/10.1016/j.bjorl.2018.02.005

Simner, J., Koursarou, S., Rinaldi, L. J., & Ward, J. (2022). Attention, flexibility and imagery in misophonia: Does attention exacerbate everyday disliking of sound? *Journal of Clinical and Experimental Neuropsychology*, *In Press*. *43*(10), 1006–1017. https://doi.org/10.1080/13803395.2022.2056581

Simner, J., Rinaldi, L. J., & Ward, J. (2024). An automated online measure for misophonia: The Sussex misophonia scale for adults. *Assessment*, *31*(8), 1598–1614. https://doi.org/10.1177/10731911241234104

Smees, R., Simner, J., Hoare, D. J., & Ward, J. (2024). Dissociable effects of hyperacusis and misophonia severity imply different mechanisms of decreased sound tolerance. *International Journal of Audiology*, *64*(9), 964–971. https://doi.org/10.1080/14992027.2024.2419558

Swedo, S., Baguley, D. M., Denys, D., Dixon, L. J., Erfanian, M., Fioretti, A., Jastreboff, P. J., Kumar, S., Rosenthal, M. Z., Rouw, R., Schiller, D., Simner, J., Storch, E. A., Talylor, S., Werff, K. R. V., & Raver, S. M. (2021). A consensus definition of misophonia: Using a delphi process to reach expert agreement. *MedRxiv*. https://doi.org/10.1101/2021.04.05.21254951

Waveform Free. (2024). *Tracktion Software Corporation*.

Williams, Z. J., Cascio, C. J., & Woynaroski, T. G. (2022). Psychometric validation of a brief self-report measure of misophonia symptoms and functional impairment: The duke-vanderbilt misophonia screening questionnaire. *Frontiers in Psychology*, *13*, 897901. https://doi.org/10.3389/fpsyg.2022.897901

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). A manual for the embedded figures tests. In *Cir.nii.ac.jp*. Consulting Psychologist Press. https://cir.nii.ac.jp/crid/1130000797434422400

Wu, M. S., Lewin, A. B., Murphy, T. K., & Storch, E. A. (2014). Misophonia: Incidence, phenomenology, and clinical correlates in an undergraduate student sample. *Journal of Clinical Psychology*, *70*(10), 994–1007. https://doi.org/10.1002/jclp.22098