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Attention, flexibility, and imagery in misophonia: Does attention exacerbate everyday disliking of sound?

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ABSTRACT

Introduction: Misophonia is an unusually strong aversion to everyday sounds, such as chewing, crunching, or breathing. Here, we ask whether misophonia might be tied to an unusual profile of attention (and related traits), which serves to substantially heighten an otherwise everyday disliking of sounds.

Methods: In Study 1, we tested 136 misophonics and 203 non-misophonics on self-report measures of attention to detail, cognitive inflexibility, and auditory imagery, as well as collecting details about their misophonia. In Study 2, we administered the Embedded Figures task to 20 misophonics and 36 non-misophonics.

Results: We first showed that the degree to which sounds trigger misophonia reflects the pattern by which they are (more mildly) disliked by everyone. This suggests that misophonia is scaffolded onto existing mechanisms rather than qualitatively different ones. Compared to non-misophonics, we also found that misophonics self-reported greater attention to detail, cognitive inflexibility, and auditory imagery. As their symptoms worsen, they also become more accurate in an attentional task (Embedded Figures).

Conclusions: Our findings provide a better understanding of misophonia and support the hypothesis that dispositional traits of attention to detail may be key to elevating everyday disliking of sound into the more troubling aversions of misophonia.

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Does attention mediate between misophonia and everyday disliking of sound?

Misophonia is a sound sensitivity characterized by unusually strong aversions to everyday sounds, which can cause anger, disgust, panic, or rage. Triggers are often human sounds originating from the mouth (e.g., chewing, crunching, breathing, and lip smacking) or can be repetitive noises like tapping and clicking. Most people can easily ignore these sounds but people with misophonia experience strong emotional reactions, which can have a profound impact on daily life (negatively impacting school, family, workplace etc.; Wu et al., 2014). In this study, we investigate what traits might contribute to the profile of people with misophonia, looking particularly at heightened attention, as well as related characteristics of cognitive inflexibility and unusually high auditory imagery. Establishing whether misophonics show unusual profiles beyond sound aversions themselves can provide valuable insight into potential underlying mechanisms for this condition.

Misophonia is relatively poorly understood, having been first recognized only recently (Jastreboff & Jastreboff, 2001). Symptoms tend to emerge in childhood or adolescence (Rouw & Erfanian, 2018), but see also Cavanna & Seri (2015), and are related to subtle organizational differences in the brain, including increased functional and structural connectivity in regions related to threat, emotion, and salience (Kumar et al., 2017; Schröder et al., 2019). This suggests sounds may have a larger salient and emotional impact on people with misophonia, compared to most other people. Here we examine this unusual salience, by looking at potential psychological mechanisms underlying it. Our hypothesis here is that heightened attention to detail (and related traits, see below) might escalate mild everyday disliking into more problematic sound aversions.

Attention to detail is the ability to allocate cognitive resources to all details of a task or environment, no matter how small (Young et al., 1989). If people with misophonia had superior attention to detail, they might overly attend to sounds that would otherwise be only

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mildly disturbing and easily ignored by other people. There are two key components to this hypothesis: the first is that people with misophonia may have attentional differences, and the second is that misophonic triggers may be sounds that are already mildly bothersome for other people (albeit to a far lesser degree).

With respect to the nature of misophonia trigger sounds, early data from Edelstein et al. (2013) suggested that misophonics and non-misophonics do indeed find the same stimuli to be aversive versus non-aversive. Their participants rated 31 sound-clips for discomfort on a scale 0–4. There was a moderate by-item correlation across misophonics and non-misophonics (r = .4). However, many items were not misophonic triggers at all (e.g., rainfall, whale song, and bird singing), and the study tested just six misophonic participants. Hence, although these results are important and intriguing, there are questions remaining about misophonic triggers themselves, and the extent to which they might be aversive for both misophonics and non-misophonics alike. We therefore address this question by testing a large group of people with and without misophonia, presenting a large number of known triggers of misophonia (see *Methods*).

The second component to our hypothesis is that mildly aversive sounds may become heightened from *a priori* traits of heightened attention. To begin, it is certainly true that people with misophonia find their aversive sounds hard to ignore. In a dichotic listening task, Silva & Sanchez (2019) showed that people with misophonia were significantly worse at attending to sentences compared with non-misophonics, if sentences were played in the presence of a misophonic sound (e.g., chewing; but no difference for other sounds). Frank et al. (2020) found similarly for misophonics attending to on-screen (visual) stimuli, both during and after hearing aversive sounds. Hence, people with misophonia are especially attentive to misophonic triggers, even at the expense of attention to other stimuli. Here, we propose that people with misophonia may also be more widely attentive, as a dispositional trait. In other words, we suggest that people with misophonia may have more general differences in attention to detail – beyond misophonic triggers. If true, this trait difference might act as a precursor to the emergence of misophonia, causing people with misophonia to overly attend to sounds that others can ignore.

Surprisingly little is known about dispositional traits of attention in misophonia. However, one study of auditory-evoked EEG potentials found significant differences between misophonics and non-misophonics during an “oddball task” (Schröder et al., 2014). Participants listened to a stream of regular beeps of 1000 Hz interspersed with oddball beeps. Data showed that misophonics had significant differences in the mean amplitudes of their N1 peak, an EEG feature linked to early attentional processing (Näätänen, 1992; Rinne et al., 2006). Another study, of people with misophonia performing a “stop signal task” (which measures response inhibition), found that misophonics favored accuracy rather than speed, and employed more attentional resources to this end (Eijsker et al., 2019); i.e., activating posterior cingulate cortices less than non-misophonics during successful inhibition, where similar deactivation suggests increasing attentional loads). More recently, Eijsker et al. (2021) have shown differences in white matter structure in regions controlling attention toward emotionally salient information. These three studies suggest that there may be broader attentional differences associated with misophonia – beyond being unable to ignore trigger sounds themselves.

However, one further study has suggested that misophonics may be broadly *in*attentive. When Frank et al. (2020) found that aversive sounds distracted misophonics from an on-screen visual task (see above), they also found a null effect suggesting they may be equally inattentive to the screen even before sounds were played. However, we suggest that participants may have been distracted by the *expectation* of sounds (because the authors based their methods on Panagopoulos et al., 2013, who did indeed forewarn participants before the study began.) Indeed, Frank et al. warn of caution when interpreting their result, suggesting future studies warrant a replication in the complete absence of sounds. In the current study, we will test more directly whether people with misophonia have heightened attention to detail using a series of measures. In Study 1, we present the *Detail and Flexibility* questionnaire (DFlex; Roberts et al., 2011) a questionnaire developed specifically to detect excessive attention to detail (and also the trait of cognitive inflexibility; see below). We will also use the Attention to detail the subscale of the *Autism Spectrum Quotient* (AQ; Baron-Cohen et al., 2001), a second measure of focused attention, and one that has successfully shown differences in other groups with heightened sensory sensitivities (e.g., synaesthetes; Ward et al., 2018). Both scales measure attention-to-detail, but the Dflex additionally taps the related trait of local processing (i.e., a detail/local-focused approach at the relative expense of global context). It was also created to avoid a potential male-bias of the AQ subscale, which (the authors suggest) had been written with the male profile of autism in mind, and may be less sensitive for female samples. We therefore included both scales for their broader focus on traits of attention (and we note the small but significant correlation across scales, $r = .26$, $p < .001$; Roberts et al., 2011). Finally, in Study 2, we will present a behavioral task known to be sensitive to the local processing/attention to detail (the Embedded Figures task; Witkin et al., 1971; see Study 2).

A second psychological trait of interest is Cognitive Inflexibility (also known as a difficulty in set-shifting, or cognitive rigidity). Flexibility is a cognitive style related to the ability to shift selectively between thoughts in response to environmental demands (Dajani & Uddin, 2015; Scott, 1962). *In*flexibility is related to poorer self-regulation and can be involved in clinical vulnerabilities, such as for obsessive-compulsive disorder (Van Passel et al., 2016) and anorexia nervosa (Maria et al., 2020). Importantly, it is also closely related to the trait of perfectionism (Ferrari & Mautz, 1997), a feature found in misophonia (Jager et al., 2020). Most importantly, models of perfectionism (Shafran et al., 2002) suggest that perfectionists show an attentional bias, which allocates greater attention to negative information than to positive information. In the case of misophonia, this would translate into an over-focusing on the negatively perceived sounds. Our use of the DFlex questionnaire to assess attention to detail (see above) also therefore offers the opportunity to explore this relationship with perfectionism (Jager et al., 2020), since the DFlex measure has subscales of both attention and (in)flexibility. We predict greater inflexibility, linked to higher perfectionism (Jager et al., 2020), and increased attention (which in daily life might include attention on the negatively perceived sounds).

The final trait of interest is auditory imagery, which we propose may also serve to enhance unwanted attention toward sounds. Auditory imagery is the mental simulation of sound in the absence of external auditory stimuli (Lima et al., 2015). An example of auditory imagery is hearing a familiar song in your head or having a mental internal dialog. Imagery is quasi-iconic (i.e., it resembles real-world sounds, albeit within the mind) but its vividness varies widely among individuals (Lima et al., 2015). These differences are also reflected in brain structure: people scoring higher on auditory imagery also show thicker gray matter in regions, such as the superior temporal gyri (Halpern, 2015). Here, we ask whether auditory imagery is different in people with misophonia, given the known relationship between imagery and attention. Moriya (2018) found that (visual) mental imagery influenced attentional guidance, so could direct attention during a (visual) search task. We therefore ask whether heightened auditory imagery may lead to similarly heightened auditory attention for sounds, thereby making it harder for people with misophonia to ignore them. To test this, we will administer an adaptation of the *Clarity of Auditory Imagery Scale* (CAIS; Willander & Baraldi, 2010), a self-report instrument that allows participants to rate their imagery for sounds, such as someone laughing or people chatting. This type of self-report questionnaire has been shown to tap imagery in a surprisingly robust way, correlating with both behavioral measures of imagery (e.g., Halpern, 2015; Keogh & Pearson, 2018) and with differences in brain structure (Halpern, 2015). We therefore predict that people with misophonia may show heightened auditory imagery, elsewhere linked to heightened attention.

In summary, we propose to test a group of people with and without misophonia (whom we will identify using the *Misophonia Questionnaire*; (Wu et al., 2014). We will then examine two different components of our theory that (a) heightened attention to detail, and related traits of increased auditory imagery and cognitive inflexibility, may lead to greater focus on (b) what would otherwise be mildly aversive stimuli for everyone else. We predict that people with misophonia will score significantly higher on attention to detail subscales of the AQ (Baron-Cohen et al., 2001) and the DFlex (Roberts et al., 2011) while also showing greater cognitive rigidity (Flexibility subscale of the DFlex), and higher auditory imagery on the CAIS questionnaire (Willander & Baraldi, 2010). Additionally, we predict a strong positive correlation between misophonics and non-misophonics in how much they dislike a large set of misophonic trigger sounds, suggesting that misophonia may arise from an unusually heightened manifestation of the everyday disliking of sounds.

Study 1

Method

Participants

Our recruitment began with 149 self-declared misophonics and 344 members of the general population, 18 + years. Self-declared misophonics were recruited via online forums where misophonia is discussed (e.g., Facebook, Reddit; Twitter), whilst our general population were recruited from the University of Sussex community. All participants were screened using the Misophonia Questionnaire (Wu et al., 2014); see below). Those exceeding the diagnostic threshold entered our misophonia group (whether from our self-declared or general population streams), while those falling below this threshold entered our non-misophonics group (see *Methods*). We excluded any self-declared misophonic (n = 38) who did not pass the MQ, along with participants with incomplete data (n = 116; since our ethics allowed participants to skip any single question if they so wished). With these procedures, n = 71 members of the general population moved into our non-misophonics group, exactly in line with the published prevalence of misophonia (Wu et al., 2014).

Our final sample contained 136 misophonics (mean age = 27.60 years, SD = 13.62; 108 female/22 males/2 non-binary/4 preferred not to say) and 203 non-misophonics (mean age = 20.19 years, SD = 4.94; 161 female/37 male/4 non-binary/1 preferred not to say). Ethical approval for both studies presented here was obtained from the Sussex University Science and Technology Ethics Committee ethics board prior to testing (approval number ER/lr290/3). Participants took part without monetary incentive, but students were offered course credit.

Materials and procedure

Participants completed our study online, using our in-house web application (www.misophonia-hub.org). This online platform is a one-stop resource containing all our tests and measures alongside advice and support for adults, children, parents, researchers, clinicians, and educators. Participants were sent a URL via e-mail to take part, which led them directly to our testing page. The study began with a request for demographic information on age, gender, etc. Participants then began our testing, which included our five measures presented in the order described below (alongside other tests to be reported elsewhere). Our task took 25 minutes to complete.

*Misophonia Questionnaire (MQ;*Wu et al., 2014). The MQ contains three sections (for Sections 1 and 2, see Study 2). Section 3, our measure here, is used to identify individuals with misophonia (Wu et al., 2014). It is a 15-point severity scale, where participants indicate any sound sensitivity and its severity, by taking into account their number of triggers, degree of distress, and impairment in their lives (Wu et al., 2014). Responses range from minimal to very severe, where scores ≥7 indicate at least "moderate sound sensitivities . . . that cause significant interference in my life and which I spend a great deal of conscious energy resisting or being affected by" (St. Clare, 2003). Individuals reporting ≥7 on this Severity Scale are considered to have clinically significant misophonia (Wu et al., 2014), since this mirrors cutoffs for other clinical conditions (e.g., National Institute of Mental Health's *Global Obsessive-Compulsive Scale*; St. Clare, 2003). This was the threshold taken in the current study to classify our participants into two groups (misophonics vs non-misophonics; see *Participants*). We found this measure to be reliable in our sample with a Cronbach's alpha of α = .92.

Sussex Misophonia Scale – Triggers (SMS-Triggers; Rinaldi et al., 2021). The Sussex Misophonia Scale includes a section (Part 1) dedicated to misophonia triggers. We included this measure to estimate how aversive are misophonic trigger sounds, for both misophonics and non-misophonics. Here, participants were presented with 48 known triggers for misophonia (e.g., *the sound of people eating*) and asked *Have you always hated these things? Or don't you mind them?* Within this test, participants first saw eight broad categories of triggers (e.g., *People eating*; see, Table 1) to which they responded individually Yes or No. If all eight responses were No, the measure ended. However, any category that responded positively revealed a full list of triggers within that category. For example, if the participant responded Yes to *I hate the sound of people eating*, this revealed further eight types of eating-sound (*crunchy foods (e.g., apples); crispy snacks; chewing; lip smacking; swallowing; slurping (a drink); wet mouth sounds (e.g., yogurt); other eating sound*; see, Table 1) along with the question *Which do you hate hearing? Tick all that apply*. In total, participants saw 48 trigger items, which are shown in Table 1.

Detail and Flexibility Questionnaire (DFlex; Roberts et al., 2011). This self-report instrument contains 24 items, which measure two aspects of neurocognitive functioning: cognitive rigidity (i.e., difficulty with flexibility; e.g., "I like doing things in a particular order or routine") and attention to detail (e.g., "I tend to focus at one thing at a time and get it out of proportion to the total situation"). Responses are given using a 6-point Likert scale (from 1 = "strongly disagree" to 6 = "strongly agree). A higher total score indicates more attentive or inflexible behaviors. Both subscales show high internal reliability, construct validity, and strong discriminant

Table 1. Triggers for misophonia, and their superordinate category.

Category	Trigger
sound of people eating	crunchy foods (e.g., apples); crispy snacks; chewing; lip smacking; swallowing; slurping (a drink); wet mouth sounds (e.g., yogurt); other
sound of repetitive tapping	pen clicking; foot tapping/ foot on floor; repetitive barking; tapping pen/ pencil; tapping finger; typing on a computer; other
sound of rustling	rustling paper; rustling plastic; other
throat sounds	throat clearing; hiccups; humming; other
sounds from mouth and nose	breathing; snorting (e.g., when people laugh); nose sniffing; coughing; snoring; whistling; sneezing; burping; other
voice sounds	certain accents; some people's voices; certain letter sounds; certain vowels; certain consonants; other
repetitive visual movements	repetitive leg rocking; foot shuffling; people rocking back and forth on their chair; other
background sounds	clock ticking; car engines; refrigerator humming; dishwasher; washing machine/ dryer; fan; other

Note that one category is non-auditory because people with misophonia can also be triggered by repetitive visual movements such as leg-swaying validity (based originally on groups with and without eating disorders; (Roberts et al., 2011)). More recently, the DFlex questionnaire was validated using a French clinical sample, where it again showed good psychometric properties in distinguishing clinical groups (Maria et al., 2020). In our own sample, we found this measure to show excellent reliability with a Cronbach's alpha of α = .91.

Attention to detail Subscale of the Autism Spectrum Quotient (AQ; (Baron-Cohen et al., 2001). The AQ is a widely used measure for identifying autistic traits, including the trait of attention to detail. The full questionnaire consists of 50 items rated using a 4-point Likert scale (definitely agree; slightly agree," "slightly disagree," "definitely disagree"). Here we presented one of its five subscales, attention to detail, which contains 10 items such as "I tend to notice details that others do not" or the reverse coded "I don't usually notice small changes in a situation or a person's appearance."[1] The total scores on this sub-scale range between 0 and 10, where higher total scores indicate stronger attention to detail. The AQ scale has previously shown acceptable internal consistency varying from α = .63 − .78 (Baron-Cohen et al., 2001; Kurita et al., 2005) and in our own sample showed α = .84. Its subscale of attention to detail reliably predicts other sensory conditions such as synesthesia (Ward et al., 2018).

The Clarity of Auditory Imagery Scale (CAIS; (Willander & Baraldi, 2010)– *Adapted*. The CAIS is a self-report instrument measuring auditory imagery, which presents verbal descriptions of sounds (e.g., a dog barking) and asks participants to rate their auditory imagery using a 5-point Likert Scale. Given our detailed work in mental imagery (Dance, Jaquiery et al., 2021) we adapted this scale in two ways. The original measure requires participants to rate how clearly they could "imagine the sounds"; however, recent work shows that mental imagery and imagination are distinct (people without mental imagery can still imagine; e.g., Dance, Jaquiery et al., 2021). We therefore rephrased the instructions as follows: *How clearly can you HEAR these sounds in your head, as if they were real sounds?* Likert labels were changed accordingly from 1 = *not at all* to 6 = *very clear (like a real sound)*, these last four words being our own addition. From the original item list of Willander and Baraldi (2010), we presented the following: a clock ticking, a dog barking, someone sneezing, a person laughing, a group of people chatting. Higher scores on the CAIS scale indicate more vivid imagery and the scale has been previously shown to have a good internal consistency of α = .88. In our own sample, we found a yet higher internal reliability of α = .92.

Analytic plan

We used R version 3.6.3 in RStudio, with the following packages (and uses in brackets): We conducted all analyses in R version 3.6.3 using RStudio. We used the following R packages to conduct our analyses: *tidyverse* (for general data wrangling), *afex* to perform (ANOVA), *stats* to perform (t-tests), and *effsize* to calculate (effect sizes). Prior to each analysis, data were checked for outliers by imposing cutoffs at 3 SDs above and below the mean; there were no outliers beyond these points so all data was retained. Where appropriate, we describe our sample descriptively in terms of using means and standard deviations (SDs) where appropriate. We also confirmed the assumptions of normality by checking QQ plots and the Shapiro–Wilk test, and we confirmed that homogeneity of variance was checked using Levene's test. We use independent-samples t-tests to investigate groupwise differences between misophonics vs non-misophonics for AQ-attention in detail and the CAIS. We used ANOVA for the DFlex (which contains two subscales). Where applicable, we applied Bonferroni correction for multiple comparisons. There were no significant differences between our two groups in terms of gender ratios (Fisher's exact test p = .428), therefore gender did not enter our modeling of dependent variables. In contrast, age was significantly different across groups (t(337) = 7.09, p < .001, Hedges' g = .79; see *Participants* for means/SDs) so was entered into our initial models. However, it was a non-significant predictor and so was subsequently dropped from our final models reported below.

Results

Do people with misophonia have greater attention to detail (AQ questionnaire)?

Within the AQ subscale of attention to detail, scores range between 0 and 10, where higher scores indicate greater attention to detail. We followed (Baron-Cohen et al., 2001) in scoring 1 point for responses of "Slightly/Definitely agree" to positively worded items (i.e., from the original AQ, items: 5, 6, 9, 12, 19, 23) and "Slightly/Definitely disagree" to negatively worded items (28, 29, 30, 49). After confirming that there were no violations in assumptions (Levene's test for homogeneity of variance: F(1,337) = 1.06, p = .305), we compared attention to detail across groups (misophonics vs. non-misophonics). Misophonics scored a mean of 5.47 (SD = 1.95), while non-misophonics scored 4.57 (SD = 2.08) and this difference was significant (t(302.64) = −4.05, p < .001), with a small-to-medium effect size (d = −0.44).

Do people with misophonia have greater attention to detail and inflexibility (DFlex Questionnaire)

Within the DFlex (Roberts et al., 2011), total scores range between 24 and 144, while each subscale of 12 items ranges from 12 to 72. Higher scores indicate greater attention to detail and inflexibility. We ran a 2 × 2 mixed ANOVA crossing group (Misophonics, Non-misophonics) with sub-scale (Attention, Inflexibility). We found a significant main effect of subscale ($F(1,337) = 59.73$, $p < .001$, $\eta^2G = 0.23$) since scores were higher overall on Cognitive Rigidity ($M = 41.80$, $SE = 0.54$) versus Attention to detail subscale ($M = 38.80$, $SE = 0.54$). More importantly, we also found a significant main effect of group ($F(1,337) = 31.24$, $p < .001$, $\eta^2G = 0.75$), indicating that misophonics ($M = 43.10$, $SE = 0.71$) scored significantly higher than the non-misophonics ($M = 37.40$, $SE = 0.71$), with no interaction ($F(1,337) = 0.48$, $p = .487$, $\eta^2G < .001$). Our data therefore indicate higher scores for misophonics on both subscales of attention to detail and cognitive inflexibility.

Do people with misophonia have higher auditory imagery (CAIS)?

Misophonic participants scored overall higher in the CAIS ($M = 18.99$, $SD = 5.42$) than in non-misophonics ($M = 17.04$, $SD = 5.42$). An independent-samples t-test showed this difference to be significant ($t(289.48) = -3.22$, $p = .001$) with a small effect size (Cohen's $d = -.34$). Results therefore support our hypothesis that misophonic people have higher clarity and vividness of auditory imagery than non-misophonics.

Are misophonic trigger-sounds also (mildly) aversive for Non-misophonics? (Sussex misophonia scale)

Our aim here was to examine whether misophonia stems from an exaggeration of dislike felt by everyone (albeit shifted upward in severity) rather than qualitative differences in trigger-class. Our analysis began with the 48 triggers of the Sussex Misophonia Scale, which were rated individually by each participant, using check-boxes to indicate if they hated the sound (vs. did not mind it). We counted the number of "hate" responses for each trigger and did this separately for misophonics versus non-misophonics. This gave us a ranking for each group, from the most-hated trigger to the least-hated trigger. We then compared the order of these rankings across participant group, using a Spearman's rank correlation. This analysis revealed a highly significant correlation ($r = .88$, $p < .001$), suggesting that the most aversive triggers for people with misophonia (e.g., chewing) were also those disliked most often by non-misophonics.

In addition to finding a strong correlation in the rankings of disliked triggers, we also found that the mean number of people disliking this set of triggers was – as expected – significantly higher for misophonics ($M = 41.02$ $SD = 28.74$) than non-misophonics ($M = 23.94$ $SD = 20.34$; $t(47) = -8.94$, $p < .001$). For the full-ordered list of triggers ranked by misophonics and non-misophonics see Supplementary Information (SI).

Discssion

Here, we tested a model of misophonia, which suggests that the sound aversions are related in part to heightened attention to detail, auditory imagery, and cognitive inflexibility. Our model produced four testable hypotheses: that results showed that misophonics would score significantly higher on attention to detail, including the component of attention implicated in local (over global) processing. They also showed two different scales ((a) from the AQ and (b) DFlex questionnaires), as well as (c) greater cognitive inflexibility on the DFlex, and (d) heightened auditory imagery on the CAIS. Our hypotheses were supported. We also predicted that the sounds that trigger misophonia would be somewhat aversive to all people (although far less), and this was also supported. We return to these results in the General Discussion. Before then, we seek objective validation of our self-report findings.

Study 2

In Study 1 we saw that people with misophonia reported greater attention to detail and related traits (inflexibility, imagery) than people without misophonia. However, our measures were self-report questionnaires. In Study 2, we provide behavioral support for these questionnaire data. One way to measure attention to detail is via its relationship with local processing. As noted above, this is the ability to focus on the fine-grained details of a stimulus, or process information in a more detailed-oriented way – for example, when locating a face in a crowd (Jolliffe & Baron-Cohen, 1997; Koldewyn et al., 2013). Previous studies have captured this by asking participants to scrutinize complex figures or patterns. The most widely known measure is the Embedded Figures Test (Witkin et al., 1971), where participants see a complex and camouflaging gestalt, and their task is to spot a simple form within the complex figure. Clinical groups with heightened attention to detail (e.g., people with autism) are found to have superior performance in this task (e.g., Jolliffe & Baron-Cohen, 1997). We therefore ask whether the Embedded Figures task can provide behavioral support for the self-reports of greater attention to detail in people with misophonia. We hypothesize greater accuracy and/or faster response times in detecting embedded figures for people with misophonia.

Method

Participants

We tested 20 misophonics (mean age = 21.2 years, *SD* = 3.7; 18 female/2 non-binary), and 36 non-misophonics (mean age = 19.9 years, *SD* = 1.3; 29 female/6 males/1 preferred not to say). As before, their group status was determined objectively using the Severity Scale of the MQ (Wu et al., 2014; see above, and *Methods* below).

Participants were recruited from the same population as Study 1. The inclusion criteria for Study 2 were (a) that participants had opted to complete the full MQ (rather than just the severity scale required for Study 1), (b) they completed our second measure in full (*Embedded Figures*, see below), and (c) they were using a device with a trackpad to guide their pointer. Our task measures response times, which differ depending on device (e.g., mouse requires greater arm-movement than trackpad). We therefore determined which device participants were using (via an on-screen question) and selected trackpad-users only because these represented our largest group. (In general, we find our test-participants are approximately 55–65% trackpad, 20% mouse, 5–10% touchscreen, with 10–20% unknown). Hence, we excluded further 30 participants using non-trackpad pointers, and additional five participants who encountered a technical problem (which inadvertently repeated trials if the participant hit refresh).

Materials and procedure

Participants completed our study online as before (see Study 1). Our task had the two components below, and took 20–30 minutes to complete.

Misophonia Questionnaire (MQ; Wu et al., 2014). The MQ contains 21 questions across three sections. Section 3 is described in Study 1, while sections 1 and 2 contain questions about misophonia sound-triggers ("Symptoms scale": 8 items) and emotions/behaviors ("Emotions and behaviours Scale" 11 items), respectively. Both are answered using a 5-point Likert Scale (0-Not at all true, to 4-Always true) and show good internal consistency (α = .86; Wu et al., 2014). In Section 1, participants indicated how many different types of sound they are sensitive to in daily life (i.e., "In comparison to other people, I am sensitive to the sound of . . . "). Here, they selected one or more from eight sound-categories, which are the most commonly known triggers of misophonia (Rinaldi et al., 2021). These sound-categories comprised: people eating, Repetitive tapping, rustling, people making nasal sounds, people making throat sounds, certain consonants and/or vowels, environmental sounds, and other. Each category was accompanied by examples (e.g., *people eating: chewing, swallowing, lips smacking, slurping, etc.*). High scores on this scale represent a greater aversion to sounds (i.e., a larger number of categories triggering misophonia). In Section 2, participants describe how they respond to their aversive sounds by selecting one or more emotions/behaviors (e.g., *Become angry? Cover your ears?*). Again, higher scores represent greater misophonia.

Participants completed the MQ once only, with their data from Section 3 cleaved off for Study 1 to determine group status, and with all three sections entering the analysis for Study 2 (with a different statistical approach; see *Results*).

Embedded Figures Test (Witkin et al., 1971). This task had 32 trials, including three practice items. Our materials were taken from an adaptation of the Embedded Figures task (Ward et al., 2018). In each trial, participants were shown a line drawing (target shape) at the top of the screen, and four complex shapes below (labeled 1, 2, 3, 4). Participants were required to select the option (1–4) which contains the target shape within it (for example, see, Figure 1). Participants were told the target shape was embedded without rotating or changing in any way. Participants had 12 seconds to respond by selecting the correct answer on screen (i.e., hovering their pointer over 1, 2, 3, or 4 and clicking to select). Participants began with practice trials providing feedback, but there was no feedback during target trials. The Embedded Figures task has been shown to be a reliable measure with an acceptable internal consistency of α = .76 (Mumma, 1993).

Analytic plan

Our statistical tool and packages were identical to Study 1, with the addition of *Hmisc* for correlations. Data were treated as in Study 1, except that analyses were independent-samples t-tests for groupwise

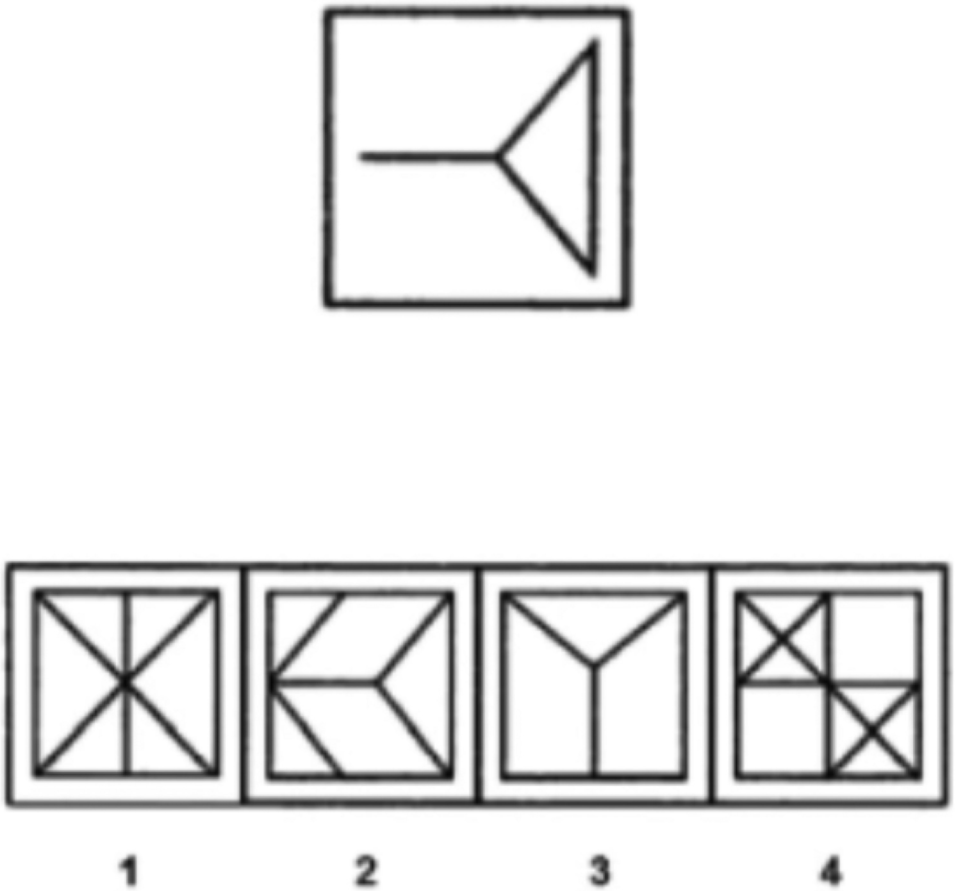

Figure 1. Example item from the Embedded Figures task. Participants must select the option (1–4) which contains the target shape within it. Here the correct answer is 2.

differences in accuracy/response time, and correlations within groups. There were no significant differences between our two groups in terms of age ($t(54) = 1.88$, $p = .065$, Hedges' $g = .53$) or gender ratio ($\chi 2$ (1) = .850, $p = .356$, Cramér V = .123); see *Participants* for descriptive statistics); therefore, age and gender did not enter our modeling of dependent variables. (Here, gender was treated as female vs. non-female, given our small sample size and three zero-cells in our 2 × 4 contingency table of Group × Gender; see *Participants*. However, applying Fisher's exact test to the sparse 2 × 4 table shows a significant difference of $p = .030$. So for added conservativeness, we also ran initial models including gender but it was a non-significant predictor, so was subsequently dropped from our final models below.)

Results

The Embedded Figures task produces an accuracy score and a response time (RT) for correct items. The MQ produces one datapoint for each of three subscales: number of triggers (aversive sounds, e.g., rustling; Section 1), the number of resultant emotions/behaviors (e.g., becoming angry; Section 2), and a severity score (Section 3; used to divide our participants into groups; see above). In our analysis, we first simply compare means in the Embedded Figures task across participant groups, asking whether people with misophonia are more accurate and/or faster than non-misophonics. Next, we examined how speed and accuracy are predicted by fine-grained information from the MQ sub-scales.

We first compared means groupwise. An independent samples t-test showed no significant difference across groups in either accuracy (misophonics $M = 19.15$, $SD = 3.62$; non-misophonics $M = 20.64$, $SD = 4.02$; t (42.99) = 1.42, $p = .163$; $d = .38$) or speed (misophonics $M = 6665.55$, $SD = 1608.12$; non-misophonics $M = 6580.67$, $SD = 1433.62$; t (35.70) = 0.20, $p = .845$; $d = .05$) with negligible-small effect sizes.

Next, we examined our data at a more fine-grained level, using all the information available across our three subscales for misophonia – rather than a simple categorical division of misophonics versus non-misophonics. We hypothesized that people with misophonia may behave differently to non-misophonics in the Embedded Figures task if we could include all the information across their full range of scores. For example, on a scale relating to trigger-sounds, this could range from just one or two types of sound (e.g., rustling) rarely experienced, to as many as eight sounds experienced very often. We therefore separately correlated Sub-scales 1 and 2 of the MQ (trigger-sounds, emotions/behavior) with speed and accuracy in our task.[2] Table 2 shows the correlation coefficients for both misophonics and non-misophonics. For people with misophonia, there was a significant relationship between accuracy and the "Symptoms scale" of the MQ (relating to number and frequency of aversive sounds (r = .63, p = .002, which survives correction; see, Table 2). Specifically, the greater the number of trigger-sounds symptoms for people with misophonia, the more accurately they performed in our attention task. No other effects were significant (see, Table 2). Finally, and importantly, MQ scores did not predict the speed of responding for either group (misophonia – all uncorrected p's ≥ .2; non-misophonics – all uncorrected p's ≥ .07), suggesting that the superior accuracy of misophonics was not simply because they slowed down.

Discussion

We tested groups of people with and without misophonia on the Embedded Figures task, a behavioral measure known to tap into attention to detail. However, in our study, we found a relationship between accuracy in the Embedded Figures task and the degree of misophonia. For our misophonia group only, the greater the misophonia symptoms (i.e., the greater the number and frequency of aversive sounds experienced in daily life), the higher the accuracy. This accuracy did not come with any response time penalty, and provides behavioral support for our self-report findings in Study 1.

Table 2. Correlation coefficients (and p values) for correlations between each of two MQ subscales (Symptoms, Emotions, and Behaviors) and accuracy (top) or response times (bottom) for both misophonics and controls.

Accuracy	"Symptoms" Scale	"Emotions and Behaviours" Scale
Misophonic	0.63 (.002*)	0.21 (.382)
Non-misophonic	−0.04 (.817)	0.25 (.146)
Response time	**"Symptoms" Scale**	**"Emotions and Behaviours" Scale**
Misophonic	0.30 (.202)	0.17 (.472)
Non-misophonic	0.03 (.855)	0.31 (.068)

Note: P values are uncorrected; Bonferroni correction for multiple comparisons sets the alpha level at .006; significant results at this new level are indicated with an asterisk

General discussion

Our research centered around the idea that dispositional differences in attentional traits might lead people with misophonia to over-attend to otherwise only mildly aversive sounds. Our data supported this hypothesis. In Study 1, we found a broad trait-profile of heightened attention to detail/local processing, as well as related traits of cognitive inflexibility, and high auditory imagery. In Study 2 we found behavioral support from the Embedded Figures task (which taps local processing/attention to detail) in that misophonics with worse symptoms (i.e., many frequent aversive trigger-sounds) performed more accurately than those with fewer aversive trigger-sounds.

Our behavioral results in Study 2 showed a specific pattern of attention in misophonia. Attentional superiority was related to the number/frequency of misophonia triggers (i.e., our correlation was with Scale 1) rather than the resultant behavior/emotions (no correlation with Scale 2). Understanding this difference provides a clearer interpretation of our results; i.e., attention-to-detail is linked with how often someone encounters misophonia triggers, and not with how much they are upset or impaired. This is a very intuitive finding: better attention relates to more easily spotting annoying sounds. Of course, this finding must be interpreted within our relatively small sample since we also found a slight trend for Scale 2 (p = .06 uncorrected against an adjusted alpha of .006). Future studies might therefore seek to replicate this finding and/or use alternative scales with more items or subscales tapping behavior/impact (e.g., Rosenthal et al., 2021; Vitoratou et al., 2021).

Our findings on cognitive inflexibility and attention to detail are particularly notable since they are also seen in a number of conditions, such as obsessive-compulsive disorder (Yovel et al., 2005), depression (Kato, 2016), and perfectionism (Ferrari & Mautz, 1997; Ong et al., 2019). Importantly, these same traits have also been linked to misophonia (Cusack et al., 2018; Eijsker et al., 2019; Jager et al., 2020). The perfectionist traits of people with misophonia can also be seen in behavioral tasks, such as the stop signal task, which measures response inhibition. Here, misophonics show longer stop-signal delays, meaning they favor accuracy rather than speed, implying traits of perfectionism (Eijsker et al., 2019). Our findings of cognitive inflexibility and heightened attention to detail also fit within this trait profile, and may produce (or at the very least correlate with) an over-attending to sounds. In this respect, misophonia may have similarities to phobias (e.g., fear of spiders) in that it elicits both behavioral avoidance of triggering stimuli but also heightened attention toward those same stimuli (Lavy et al., 1993; Thorpe & Salkovskis, 1997; Watts et al., 1986), perhaps stemming from a trait disposition.

Regarding misophonic triggers themselves, we also found evidence to support our theory that these triggers are already mildly aversive for all people (Edelstein et al., 2013). We therefore suggest that attention to detail could over-emphasize what are already (mildly) problematic sounds because the sounds disliked by misophonics were largely similar to those disliked by non-misophonics. In other words, we found that misophonia triggers are aversive for all people, in a similar pattern that they become more aversive for misophonics (i.e., a strong positive correlation in disliking triggers across both misophonics and non-misophonics). This suggests that the mechanisms driving misophonia may stem – at least in part – from the same underlying valence judgments in the general population, albeit with an overlay of more extreme emotions.

We now turn to our final hypothesis that misophonics may have more vivid experiences when mentally stimulating sounds are within their auditory imagery. Misophonics scored significantly higher in auditory imagery, showing that they "hear" sounds internally (e.g., laughing) more clearly in their mind than do non-misophonics. Imagery self-report questionnaires have been shown to tap imagery in a surprisingly robust way, correlating with behavioral measures of imagery (e.g., Halpern, 2015; Keogh & Pearson, 2018) and brain structure (Halpern, 2015). We hypothesized heightened auditory given the known relationship between imagery and attention, in which imagery can encourage attentional guidance (Moriya, 2018). We therefore suggest that the heightened auditory imagery attention may lead to similarly heightened auditory attention for sounds, thereby making sounds harder to ignore.

Our finding of superior scores in auditory imagery might also be interpreted in light of Dance, Ward et al. (2021) who found that mental imagery is highest in those with higher sensory sensitivities. Misophonia is itself a form of high sensory sensitivity, which means it may be no surprise to find that imagery is also higher. Importantly, Baddeley & Andrade (2000) propose that for increased vividness of imagery, more sensory information may be required to be available to appropriate systems in working memory. Hence, high attention to the details of a sound may gather more information to bolster high auditory imagery. Alternatively, high imagery may itself cause higher attention to detail, and future research might profitably examine the relationship and directionality of these two characteristics. Future research might also consider differences across genders, since our samples were predominantly female (a limitation of our study). This female-bias may reflect an as-yet-unknown gender bias in misophonia, although equally likely is the well-known participation bias in which women self-refer more often to studies than men (Curtin et al., 2000; Singer et al., 2000) and are more willing to self-disclose information (Dindia & Allen, 1992). This widely occurring bias has been known to unhelpfully skew epidemiological estimates on gender in other conditions (for discussion, see Simner & Carmichael, 2015). We therefore note this with caution here and make no assumptions about whether our sample reflects a wider female bias in misophonia.

In summary, we have seen how misophonia is linked with several key traits and characteristics beyond a mere disliking of sounds. Our data show that people with misophonia are more attentive to detail, cognitively inflexible, but superior at mentally imaging sounds. Establishing these differences sets the stage for future research on the underlying mechanisms of misophonia and targeted interventions while adding a new dimension to what we understand about the mental profiles of people with misophonia.

Notes

1. Here we report only attention to detail questions, these being items 5,6,9,12,19,23,28,29,30,49 from the full scale. However, our tests were embedded in a larger battery, which included the full AQ measure. Results pertaining to autism per se are outside the scope of this study and are to be reported elsewhere.
2. We could not correlate speed/accuracy against the third subscale (Severity subscale) because responses on this subscale have a different range for misophonics (who can score 7–15; i.e., a 9 point scale) versus non-misophonics (who can score 1–6; i.e., a 6 point scale). Correlations on a restricted range have a naturally smaller coefficient, meaning we could not make a suitable comparison across groups. Nonetheless, the concept represented by the Severity subscale (which asks readers to evaluate the number of triggers, their emotional consequences, and their impact in daily life) are also found within the remaining two scales (which ask about triggers-Scale 1, and emotions/behaviors-Scale 2).

Disclosure statement

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

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