UNDERSTANDING THE RELATIONSHIP BETWEEN MISOPHONIA AND MUSICAL MEMORY, EMOTION, AND CATEGORIZATION

by

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Abstract

Misophonia is a disorder characterized by strong, negative emotional responses to specific auditory stimuli, such as chewing or tapping. This thesis investigates the relationship between misophonia and music, two seemingly unrelated topics in human auditory processing. Despite their apparent dissimilarity, they share a common thread: music often elicits strong emotional responses, even in individuals with misophonia. Building upon the hypothesis that heightened emotion enhances memory, this study explores how misophonia relates to musical memory and emotion categorization. A total of 72 participants recruited from Amazon Mechanical Turk (Low Misophonia: $n = 42$, High Misophonia: $n = 30$) completed a series of tasks including a memory encoding task, beat alignment filler task, and melody recognition task. Contrary to expectations, participants in the high misophonia group did not demonstrate significantly different performance compared to those in the low misophonia group across the tasks. However, analyses revealed significant findings among participants as a whole, irrespective of misophonia severity, particularly in relation to musical memory and emotion categorization. These findings contribute to our understanding of music's interaction with misophonia and shed light on broader aspects of music processing. While the results did not support the initial hypothesis, they provide valuable insights into the complex interplay between auditory stimuli, emotion, and memory. Further research in this area may uncover additional nuances in individuals affected by misophonia. Overall, this study advances our knowledge of the cognitive and emotional mechanisms underlying misophonia and music processing, offering implications for theoretical frameworks within the fields of psychology and neuroscience.

Keywords: misophonia, music, memory, emotion

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Introduction

Misophonia, a term that directly translates to “hatred of sound,” is an often-misunderstood auditory condition that has garnered increasing attention within the realms of psychology and neuroscience. Notably, Jastreboff and Jastreboff (2001) defined misophonia's core components as a heightened aversive emotional response to trigger sounds, which encompass a range of everyday noises such as chewing, tapping, or breathing. These negative responses do not seem to be elicited by general psychoacoustic features of a sound (e.g., loudness or pitch), but rather by the specific meaning to an individual (Swedo et al., 2022). The bulk of misophonia research has centered around its maladaptive nature, shedding light on the distressing emotional and physiological responses experienced by individuals with this condition (e.g., Rouw & Erfanian, 2017). These emotional responses are usually negative in nature and include emotions such as disgust, anger, an urge to escape, and distress. However, a small but growing body of research has suggested that individuals with misophonia may have heightened emotional responses to sounds more generally, not just trigger sounds. The present study expands upon this work to investigate whether individuals with severe misophonia symptoms have enhanced memory for emotionally salient musical melodies compared to individuals with little-to-no misophonia symptoms.

Characterizing Misophonia

Trigger Sounds and Responses

Although sounds that serve as misophonic triggers can be considered irritating by many, they do not cause such negative reactions in the general population (Schroder et al., 2013). Emotional responses of misophonia include anger, extreme irritation, and disgust, avoidance, and feelings of being overwhelmed by the sound (Brout et al., 2018). Although anger and irritation are primary reactions, aggressive outbursts are seldom reported. Verbal aggression may occur, but physical aggression is rare; non-expressed aggression is considerably most common (Jager et al., 2020, Schroder et al., 2013; Taylor, 2017). It is important to note that while human-made sounds tend to be the dominant triggers, each person with misophonia has their own specific set of trigger sounds, and seemingly any sound has the potential to be included (Edelstein et al., 2020; Schroder et al., 2013). This means that while chewing, breathing, and sniffling tend to be common trigger sounds amongst those with misophonia, some may also find that keyboard clicking, clock ticking, and other repetitive non-human-made sounds elicit a response. Visual triggers are often reported as well. Jager et al., (2020) found when visual triggers were reported, they occurred secondary to auditory triggers and had less impact than the auditory triggers. When visual and auditory stimuli occurred simultaneously (e.g., hearing and seeing someone chewing gum), subjects reported a more intense response.

Misophonia Comorbidity

Misophonia symptoms have been found to overlap with a wide range of classified DSM disorders, including autism spectrum disorder (ASD), post-traumatic stress disorder (PTSD), social phobia, and obsessive-compulsive disorder (OCD) (Schroder et al., 2013; Taylor, 2017; Wu et al., 2014). In a prior investigation, Babalola and Van Hedger (2023) examined several individual difference measures thought to relate to misophonia symptoms. The study sought to answer some fundamental questions about how the condition of misophonia covaried with musical training and reward, depression, trait anxiety, ASD, and PTSD. It was found that participants with misophonia reported significantly greater amounts of PTSD, ASD traits, anxiety, and depression, corroborating findings of previous studies. PTSD is one of the most common comorbid disorders in individuals with misophonia, and its presence is associated with the severity of misophonic symptoms (Siepsak et al., 2020). Furthermore, trauma is known to reduce distress tolerance and cause dysregulation in the autonomic nervous system, potentially contributing to the development of misophonia (Khiron Clinics, 2021). Individuals with misophonia often encounter triggers that cause annoyance, anxiety, and depression, leading them to respond by attempting to avoid or escape the stimulus (Palumbo et al., 2018). However, there are conflicting studies such as Jastrebroff and Jastrebroff's (2015, p.381) who found a low prevalence (2.2%) of psychiatric comorbidity in a sample of patients in an audiology clinic. Little further information was presented in that report, making it difficult to interpret the findings. For example, it was unclear why the patients presenting to an audiology clinic were selected for an assessment of mental disorders by a physician. Therefore, more research is needed to better understand the psychiatric correlates of misophonia. Current research can tell us that misophonia seemingly occurs as a standalone clinical condition, but is associated with a range of psychiatrics symptoms and disorders.

Underlying Mechanisms of Misophonia

As a standalone condition, a considerable amount of research has been done to understand the brain basis and mechanisms of misophonia. As previously mentioned, although most trigger sounds tend to be repetitive, negative responses do not seem to be elicited by general psychoacoustic features of a sound (e.g., loudness or pitch), but by the salience of the sound (Swedo et al., 2022). A few studies have used brain imaging to examine neural activity during misophonic reactions. Kumar et al. (2012) used functional magnetic resonance imaging (fMRI) to reveal brain responses in the amygdala and the auditory cortex while listening to unpleasant sounds. This study uncovered a noteworthy finding: the amygdala appears to store data related to both the emotional significance and acoustic attributes of sounds, influencing the interaction between the amygdala and auditory cortex. This discovery suggests a potential mechanism by which the auditory cortex could become excessively reactive, potentially explaining the unusual sensory responses observed in individuals with misophonia. Schroder et al. (2019) utilized fMRI and electrocardiography to identify the brain regions involved during an emotional misophonic reaction. Supporting the role of salience, they found that compared with controls, those with misophonia had increased activation of brain areas associated with auditory processing and the salience network (the insula, anterior cingulate cortex, and superior temporal cortex). This suggests that salience attribution to misophonic cues may underlie the symptoms observed in misophonia (Schroder et al., 2019). Combining these findings, we can theorize that first, misophonic triggers elicit physiological arousal and negative emotions. Subsequent exposure to these triggers heightens activity in the salience network, indicating a conditioned response where the neutral stimulus becomes increasingly linked with heightened negative emotions and heightened vigilance.

Misophonia and Musical Reward

Although misophonia is often associated with negative emotional reactions, a small but growing body of literature has started to investigate potential auditory benefits associated with misophonia. Misophonia is characterized by heightened attention and (typically negative) emotional responses to sounds, but an alternative theoretical explanation is that individuals with misophonia experience more intense emotional responses to *both* pleasant (non-trigger) and unpleasant (trigger) sounds. If this is the case, then it is possible that individuals with misophonia would have stronger *positive* responses to non-trigger sounds. One means of assessing this is to test individual responses to music, as music is not considered a misophonia trigger and is generally found to be rewarding (Blood & Zatorre, 2001; though see Mas-Herrero et al., 2014).

This hypothesis was tested by Babalola and Van Hedger (2023). In this study, musical reward was assessed through the Barcelona Musical Reward Questionnaire (BMRQ), a validated measure for assessing individual differences in experiencing music-evoked reward. The BMRQ encompasses five main facets: musical seeking, emotion evocation, mood regulation, sensory-motor, and social reward (Mas-Herrero et al., 2013). From this, it was found that participants with higher misophonic symptoms also scored higher on the emotion evocation subscale of the BMRQ compared to participants in a control (no misophonia) group. Scoring high on the emotional evocation section of the BMRQ indicates a strong propensity to experience intense emotional responses when engaging with music (Mas-Herrero et al., 2013). Individuals who score high on this section are likely to have a heightened ability to evoke and experience emotions in response to music, suggesting a stronger emotional connection and responsiveness to musical stimuli. This heightened emotional evocation may reflect a strong emotional impact of music on the individual, potentially influencing their overall music reward experiences and emotional engagement with music-related activities.

These findings align with Rice et al.'s (2022) research exploring the potential link between misophonia and musical frisson (chills), sound-induced emotional phenomenon characterized by positive affect and strong emotional responses to music, raising questions about the potential overlap underlying these sound-induced emotional experiences. The study showed that individuals with more severe misophonia symptoms felt more stimulated and experienced musical frisson more intensely compared to the control. These findings provide a more well-rounded perspective of misophonia, emphasizing the heightened emotional experiences provoked by specific sounds (both positive and negative). The potential for individuals with misophonia to exhibit stronger emotional reactions to music raises intriguing questions about the interplay between emotional responses and memory formation in the context of musical experiences. Given the associations between emotion and memory, particularly the impact of emotional connotations on memory retention, it is reasonable to hypothesize that individuals with misophonia could demonstrate enhanced memory for music, especially when the music carries strong emotional significance.

Misophonia, Music, and Memory

Music plays an important role in many people's daily lives. Many people listen to music from early in the morning until late at night, whether for recreation, distraction, or mood enhancement (Schaefer et al., 2013). Although the functions of music listening are multifaceted, one consistently identified reason why individuals listen to music is because music offers a particularly powerful means of representing and even inducing emotional states in listeners (Justin & Västfjäll, 2008). Music listening for the purposes of mood regulation occurs regularly and in everyday life for many people, consciously and unconsciously (Stewart et al., 2019). Music has been shown to be an effective mood regulator, with the ability to change, generate, maintain, or improve emotions and moods in daily life for personal benefit and direct coping (van Goethem and Sloboda, 2011). This may particularly resonate for those with misophonia, as listening to music has been expressed as a common coping strategy to drown out trigger sounds and mitigate the intensity of their reactions (Morales Guiterrez, 2023).

Music has been shown to evoke powerful emotional responses, with emotionally charged musical pieces being remembered more effectively than neutral ones (Cardona et al., 2022), underscoring the idea that emotional salience significantly influences and alters memory. Emotional salience is a type of relevance cue used by our memory system to prioritize information, making it more memorable than neutral information (Alger & Payne, 2019). The emotional dimensions of music, such as arousal and valence, have been found to play a crucial role in shaping musical memory, with emotionally charged musical pieces being remembered more effectively than neutral ones (Nineuil et al., 2020). Memory and emotions share some brain structures, particularly the limbic system. Emotions arise in the limbic system and become conscious when areas of the associative cortex are activated (Eschrich, 2008). The limbic system's general functions include controlling autonomic-affective responses, emotional conditioning, and conscious emotional states (Eschrich, 2008). The adverse reaction to sounds experienced by individuals with misophonia is driven by enhanced limbic and autonomic responses (Aryal & Prabhu, 2023). This suggests that misophonia is characterized by abnormal connections between the auditory, limbic, and autonomic systems, which strengthens emotional and automatic reactions. It has been hypothesized that the brain basis of misophonia is a disruption or malfunction in the interaction between the limbic system and the classical and non-classical pathways involved in sound processing (Aryal & Prabhu, 2023). This breakdown can result in an increase in emotional and automatic responses to auditory stimuli. Essentially, there is a disruption in the typical functioning of the systems involved in sound processing and response, which contributes to the heightened reactions associated with misophonia.

Due to the connection between misophonia and memory through the limbic system, it can then be hypothesized that individuals experiencing misophonia might exhibit an increased memory for highly emotionally charged songs. The limbic system's role in processing emotions and forming memories means that the heightened emotional responses associated with misophonia could extend to music. To date, little research has focused specifically on the positive reactions those with misophonia may experience, specifically regarding emotionally valenced music. In the present study, our focus is to understand if those with misophonia show an enhanced memory for stronger emotional song excerpts (compared to more neutral emotional song excerpts). The present study tested three main hypotheses. First, it was hypothesized that the high misophonia group would show a better memory for the intense emotional songs compared to the control group (H1). Second, it was hypothesized that the high misophonia group will be better at categorizing each excerpt into an emotional group (fear, tender, sad, or happy) and like the melodies more (H2). Third, it was hypothesized that the control group would perform better on the beat alignment task compared to the misophonia group (H3).

Method

Participants

We re-recruited 107 participants from the main phase of a previous study (Babalola & Van Hedger, 2023). Participant eligibility for the current study was determined based on responses to the Amsterdam Misophonia Scale (A-MISO-S) and subsequent measures, in addition to data quality assessments (see *Participant Inclusion* for details). From this main study, 107 participants (low misophonia: n = 67; high misophonia: n = 40) were invited to complete the current study, with 72 participants (low misophonia: n = 42; high misophonia: n = 30) ultimately completing the study. Participants across groups were statistically matched in terms of demographic variables (age, gender, education, and race/ethnicity), but differed as expected on reported misophonia. Participants were recruited from Amazon Mechanical Turk via CloudResearch (Litman et al., 2017), with all participants successfully passing internally administered attention checks from CloudResearch. Participants were treated in accordance with the Declaration of Helsinki, and the study protocol was approved by the Huron University Research Ethics Board.

Materials

Musical Soundtrack Clips

Participants were presented with short clips from a validated emotional film soundtrack database originally reported by Eerola and Vuoskoki (2011). From this database, four emotional categories were selected for use in the current study: Tender, Happy, Sad, and Fear. Each of these categories was further divided into two subcategories: High Intensity and Moderate Intensity. Both emotion category and intensity were validated by Eerola and Vuoskoki (2011). This division resulted in eight categories: Tender High, Tender Moderate, Happy High, Happy Moderate, Sad High, Sad Moderate, Fear High, and Fear Moderate. In each category, four soundtracks were selected, for a total of 32 distinct soundtracks clips used in the study. The length of the clips ranged from 12 seconds to 21 seconds. Examples of soundtracks used included: *Shine* (Tender High), *Oliver Twist* (Tender Moderate), *Batman* (Happy High), *Grizzly Man* (Happy Moderate), *The English Patient* (Sad High), *Dracula* (Sad Moderate), *Hannibal* (Fear High), and *The Fifth Element* (Fear Moderate).

Beat Alignment Task

A short "beat alignment" task was used as a filler between memory encoding and recognition, as is typical in memory paradigms to ensure that memory performance reflects nascent long-term memories. This task, which has been validated in prior research, had participants listen to a "beep track" played with a musical excerpt (akin to a metronome) and determine if the beeps align with the beats of a song. This task was also used to see if the repetitive nature of the beep track would be deemed distracting to participants with misophonia. The stimuli were taken from Harrison and Müllensiefen (2018).

Procedure

Eligible participants were re-invited to complete the current study via a personalized email announcement, sent through CloudResearch. Eligible participants had 30 days to complete the study from its launch, which occurred one year following the initial study. After providing informed consent, participants completed an auditory calibration, in which they were able to adjust their computer's volume to a comfortable listening level. The auditory calibration additionally consisted of a headphone assessment (Woods et al., 2017); however, headphone use was not required for participation and this assessment was not analyzed in the present study.

Following the auditory calibration, participants completed the memory encoding portion of the task. Participants listened to 16 of the total 32 musical soundtrack clips (two from each of the eight emotion/intensity categories, randomly determined). Following each clip, participants were asked to rate how much they liked the musical clip on a Likert scale ranging from 1 (*Not at all*) to 7 (*Extremely*).

Following the memory encoding portion of the study, participants completed the beat alignment task. Participants completed two practice trials with feedback, and then completed 12 scored trials with no feedback. Each scored trial consisted of two versions of a melody – one with a correctly aligned beep track, and one with an incorrectly aligned beep track (either too fast or too slow). The incorrect stimuli were shifted too early or too late by 15.75%, which, based on prior norming data (Harrison & Müllensiefen, 2018), was expected to yield approximately 65% accuracy in the task.

Following the beat alignment task, participants completed the memory recognition task. Participants were presented with all 32 soundtrack clips – 16 heard previously in encoding ("targets") and 16 new clips from the same emotion/intensity categories ("foils"). Clips were presented in a randomized order. Participants were asked to rate each song on a Likert-type scale ranging from 1 *(Definitely new)* to 7 *(Definitely old).* Participants were also asked to indicate which emotional category (Tender, Fear, Happy, Sad), they thought the song belonged to. Following this categorization of each clip, participants were asked a final Likert-type question about how intensely they thought the music clip represented the identified emotion, on a scale from 1 (*Not at all*) to 7 (*Extremely*). Upon completion of the memory recognition task, participants were provided with a debriefing form, a unique completion code, and compensated with $10.00 USD. Altogether, the completion of the study took approximately 30 minutes.

Participant Inclusion

To be reinvited, participants had to have completed the initial study conducted in 2023, as this was a continuation of said study. If the participants were able to access the study through Amazon Mechanical Turk, then they were eligible to participate. Seeing as this was an online study, a stable internet connection was required for the duration of the study as well as access to a working computer or tablet. Participants had to be 18 years old or older and be English-speaking to participate. Additional participant requirement parameters were set through CloudResearch, a service that interfaces with Mechanical Turk in participant recruitment. The additional parameters included (1) recruiting CloudResearch approved participants (who have passed previous attention checks), and (2) recruiting participants with at least a 90% approval rating from their prior tasks on Mechanical Turk. Although this study involved the re-recruitment of participants, it should be noted that it was done in a manner that does not identify the participants to the researchers. Specifically, using CloudResearch and Amazon Mechanical Turk, we only had access to an anonymized worker IDs, which could be used as a specific qualification filter for the study. Thus, the study was only visible to these participants, without the researchers knowing who these participants were.

Data Analysis

Data were analyzed in JASP. A series of repeated measures ANOVAs were used to assess group differences between the low and high misophonia group for the memory encoding and recognition. When warranted, post-hoc tests were conducted using Holm-Bonferroni corrections. An independent samples t-test was used to assess group differences for the beat alignment task. When analyzing memory recognition, a mean memory score was calculated by subtracting the confidence ratings for foil melodies from the confidence ratings for target melodies (i.e., a higher score reflects better memory).

Results

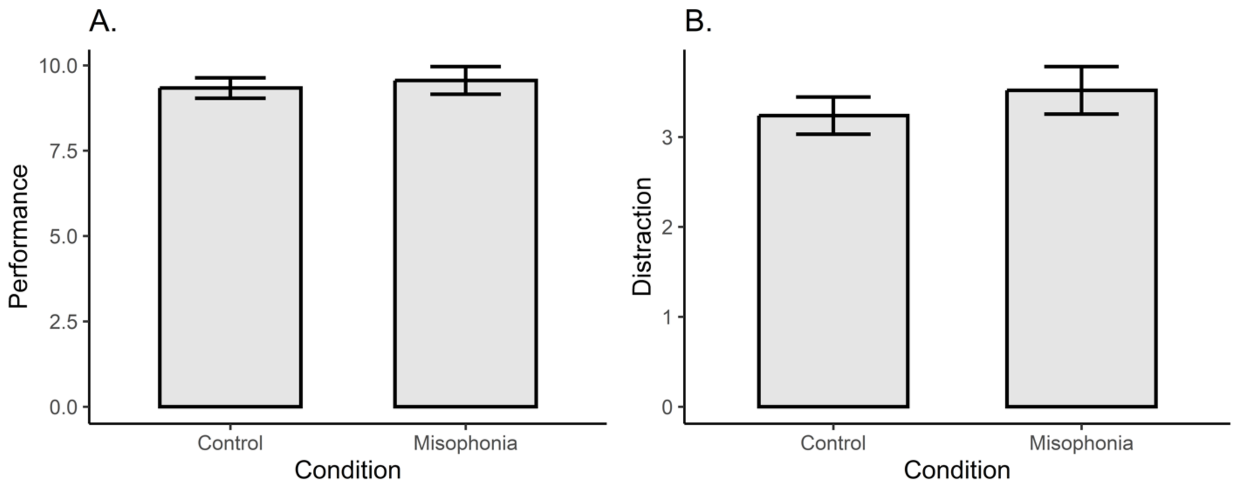
Beat Alignment

Independent samples *t*-tests were conducted to compare the mean scores of beat alignment between the high misophonia and control group. The results revealed no significant difference in beat alignment between the high misophonia (M = 9.56, SD = 0.40) and the control group (M = 9.33, SD = 0.30), $t(67)$ = -0.45, p = .654.

Similarly, no significant difference was observed in distraction levels between the high misophonia group (M = 3.52, SD = 1.37) and the control group (M = 3.24, SD = 1.34), $t(67)$ = -0.84, p = .403. Figure 1 plots the group comparisons on beat performance (A) and self-reported distractions (B).

Figure 1

Beat alignment performance (A) and self-reported distraction (B) plotted as a function of participant group.



Note: Error bars represent plus or minus one standard error of the mean.

Memory Encoding

A 4 (emotion: fear, sad, tender, happy) x 2 (intensity: high, moderate) x 2 (condition: misophonia, control) mixed analysis of variance was used to assess liking ratings during memory encoding. Emotion and intensity were within subject measures, whereas condition was a between subject measure.

There was a significant main effect of emotion on liking ratings, $F(3, 201) = 12.03$, $p < .001$. Post-hoc tests showed that participants liked the fear emotion melodies significantly less than other emotions (All *p*s < .001). There was no significant main effect of intensity on liking ratings, $F(1, 67) = 0.05$, $p = .829$. There was no significant main effect of condition on liking ratings, $F(1, 67) = 2.67$, $p = .107$. There was a significant interaction between emotion and intensity on liking ratings, $F(1, 67) = 2.12$, $p < .001$. Post-hoc tests revealed that high intensity fear resulted in significantly reduced liking ratings, compared to moderate intensity fear. For other emotions, there was no meaningful effect of intensity on liking ratings. No other term was significant in the model, including the main effect and all interactions related to misophonia group.

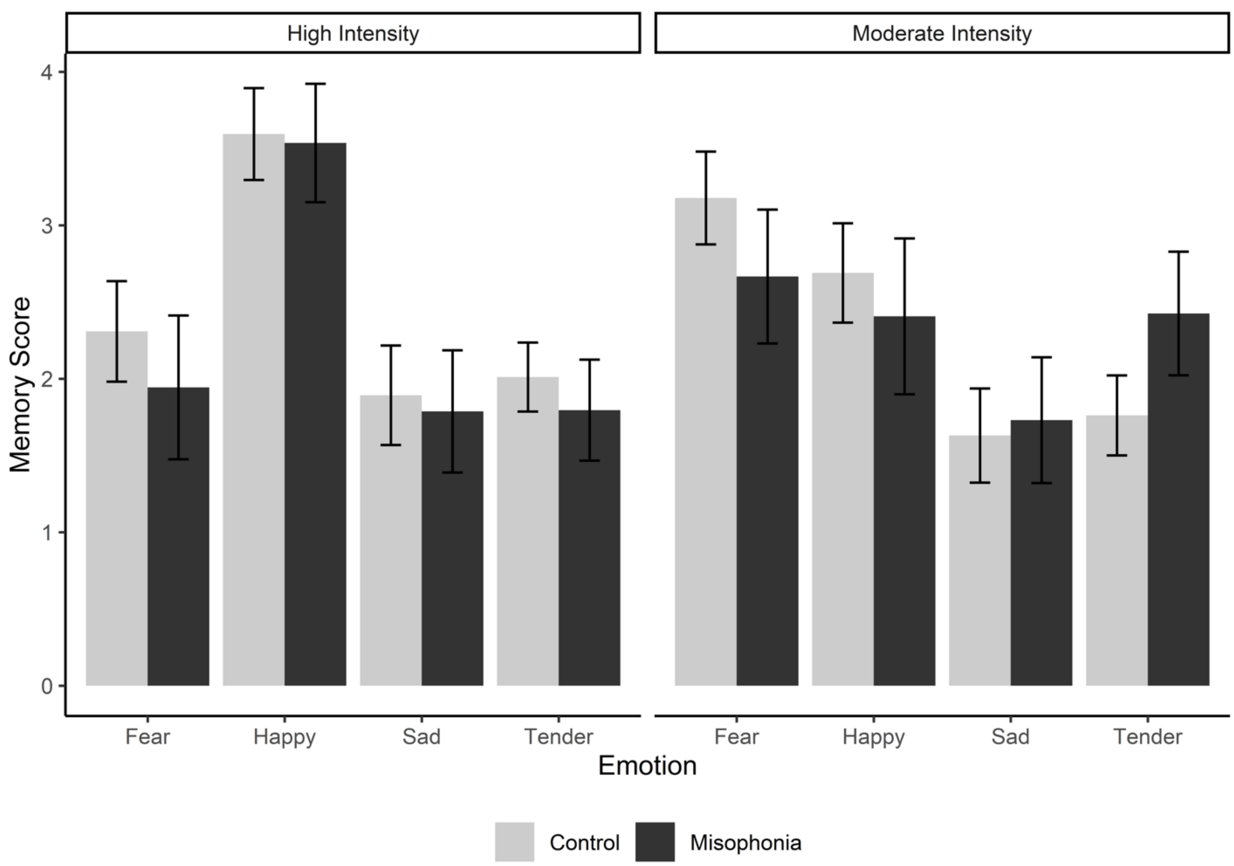
Memory Recognition

A 4 (emotion: fear, sad, tender, happy) x 2 (intensity: high, moderate) x 2 (condition: misophonia, control) mixed analysis of variance was used to assess memory recognition. Emotion, and intensity were within subject measures, whereas condition was a between subject measure.

There was a significant main effect of emotion on recognition, $F(3, 195) = 15.26$, $p < .001$. Post-hoc tests showed that participants' memory recognitions scores were significantly higher for happy excerpts compared to fear ($p = .031$), sad ($p < .001$), and tender ($p < .001$) excerpts. Additionally, memory recognition scores for fear excerpts were significantly higher than scores for both sad ($p = .002$) and tender ($p = .031$) excerpts. There was a significant interaction between emotion and intensity, $F(3, 195) = 9.95$, $p < .001$. This interaction was driven by the fear and happy emotion categories, with moderate intensity fear resulting in better memory performance compared to high intensity fear and high intensity happiness resulting in better memory performance compared to moderate intensity happiness. In contrast, intensity did not influence memory performance for either sad or tender excerpts. No other term was significant in the model, including the main effect and all interactions related to misophonia group. The results from the memory recognition portion are plotted in Figure 2.

Figure 2

Memory performance as a function of emotion intensity, emotion category, and participant group.



Note: Error bars represent plus or minus one standard error of the mean.

Emotion Categorization

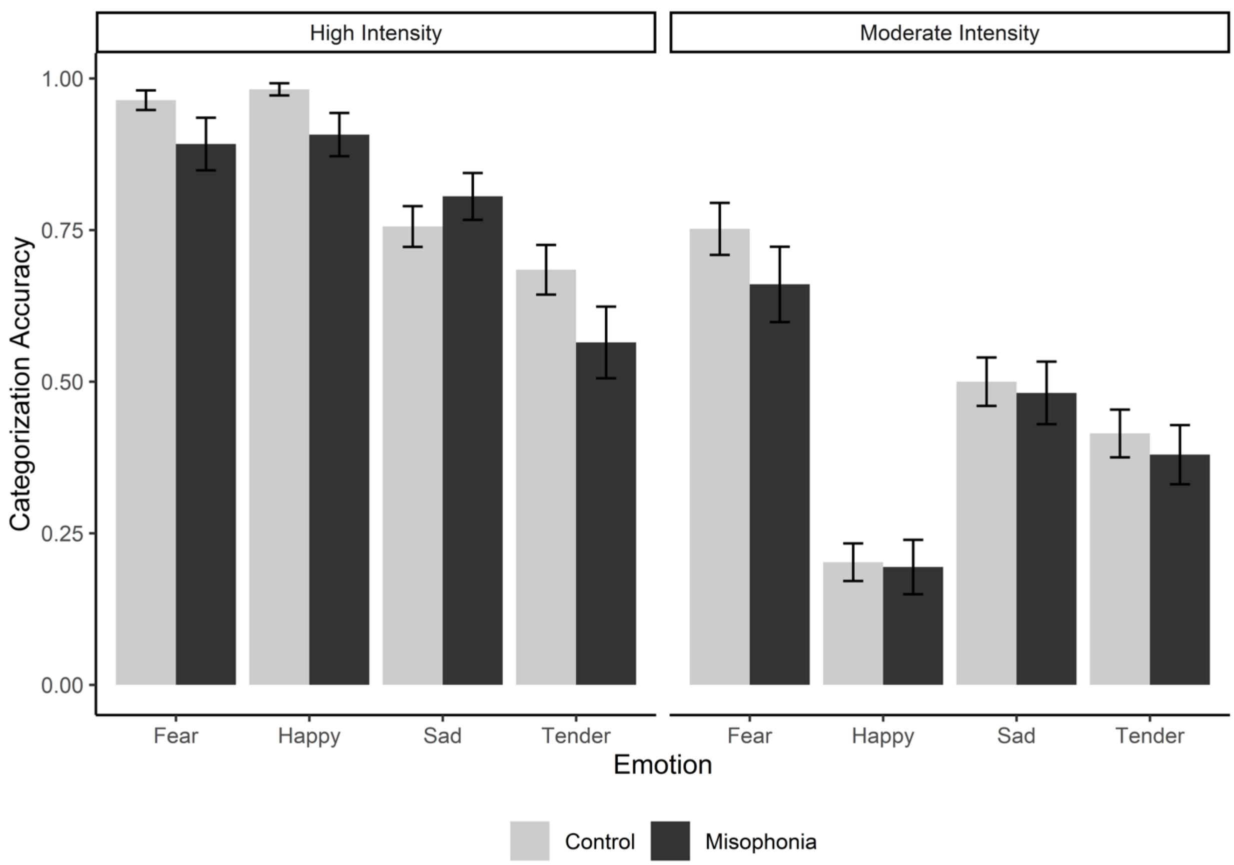
A 4 (emotion: fear, sad, tender, happy) x 2 (intensity: high, moderate) x 2 (condition: misophonia, control) mixed analysis of variance was used to assess participants' ability to correctly identify which emotional category each song belonged to.[1] Emotion and intensity were within subject measures, whereas condition was a between subject measure.

There was a significant main effect of emotion on categorization, $F(3, 201) = 45.99$, $p < .001$. Post-hoc test revealed fear songs were categorized more easily than happy, sad, and tender ($p < .001$), sad songs were categorized more easily than tender ($p < .001$), and happy songs were categorized more easily than sad and tender ($p = .042$). There was a significant main effect of intensity on categorization, $F(1, 67) = 44.69$, $p < .001$. Post-hoc tests showed that high intensity songs were categorized more easily than moderate intensity songs ($p < .001$). There was no significant main effect of condition on categorization, $F(1, 67) = 2.54$, $p = .116$. There was a significant interaction between emotion and intensity, $F(3, 201) = 44.69$, $p < .001$. This interaction was driven by moderate intensity happy excerpts, which had significantly lower categorization accuracy than all other emotion intensity categories ($p < .001$). No other term was significant in the model, including the main effect and all interactions related to misophonia The results from the memory recognition portion are plotted in Figure 3.

[1] According to the categories described by Eerola and Vuoskoki (2010)

Figure 3

Emotion categorization accuracy plotted as a function of emotion intensity, emotion category, and participant group.



Note: Error bars represent plus or minus one standard error of the mean

Emotion Intensity

A 4 (emotion: fear, sad, tender, happy) x 2 (intensity: high, moderate) x 2 (condition: misophonia, control) mixed analysis of variance was used to assess participants' perceived intensity of the songs. Emotion and intensity were within subject measures, whereas condition was a between subject measure.

There was a significant main effect of emotion on intensity**,** $F(3, 201) = 7.43$, $p < .001$. This main effect was driven by the happy excerpts, which were rated as overall more intense than fear ($p = .017$), tender ($p < .001$), and sad ($p = .001$) excerpts. There was a significant main effect of intensity on intensity, $F(1, 67) = 185.82$, $p < .001$, which independently validates the findings from Eerola & Vuoskoski (2011). There was no significant main effect of condition on intensity, $F(1, 67) = 0.20$, $p = .660$. There was a significant interaction between emotion and intensity, $F(3, 201)$, $p = .009$. This interaction was driven by the high intensity happy excerpts, which were rated as significantly higher than the high intensity sad (*p*s = .002) and tender ($p < .001$) excerpts. Additionally, high intensity fear excerpts were rated as significantly higher than the high intensity tender excerpts ($p = .021$). In contrast, there were no significant differences in intensity ratings across the emotion categories for the moderate intensity excerpts. No other term was significant in the model, including the main effect and all interactions related to misophonia group.

Discussion

The current study investigated whether those with misophonia would have a better musical memory compared to those without. Specifically, we hypothesized that participants with misophonia would have a better memory for emotionally intense music compared to control participants (H1), that participants with misophonia would be better at judging the emotional category of each musical excerpt and would like the melodies more (H2), and that participants with misophonia would perform more poorly on the "filler" beat detection task, as well as find the filler task to be more distracting (H3). Contrary to our predictions, we did not find supporting evidence for any of these hypotheses, meaning the present study did not support the notion that misophonia relates to musical memory performance, emotion categorization, or beat alignment.

There are many potential reasons for these null differences between groups, one being the sample size of the study. Although there was a reasonable sample size, it was not large, especially considering the between-participant design. Thus, it is possible that some of the null findings may be attributed to Type II Errors, resulting from the study being underpowered to detect smaller effect sizes. For example, there was a trend towards the misophonia group liking melodies more overall (p = .107), but this should be interpreted with caution - with a larger sample size, it could be determined if this represent a real (but small) effect or is just due to sampling error.

A more theoretically driven reason for the lack of effects between participant groups could be that emotions are contextually driven. A study by Coutinho and Scherer (2016) sought to understand the extent to which laboratory research on affective reactions to music approximates real listening conditions in dedicated performances. They measured emotions experienced by participants that attended a live performance at a church recital (Context 1) versus participants that watched an audiovisual recording of the same performance in a university lecture hall (Context 2). It was found that participants that watched the live performance as opposed to the recording in a laboratory setting, achieved statistically higher levels of emotional convergence in the live performance than in the laboratory context, and the experience of particular emotions was determined by complex interactions between auditory and visual cues in the performance. This study demonstrates the contribution of the performance setting and the performers' appearance and nonverbal expression to emotion induction by music, encouraging further systematic research into the factors involved. Therefore, in the current study, a "sterile" environment without much visual context for the songs the participants are listening to, might not tap into key characteristics of misophonia and emotion evocation through the controlled environment.

Although we did not find support for H3 (that the control group would perform better on the beat alignment task compared to the high misophonia group and find it less distracting), the findings from the present study are still informative. Although the beeps were repetitive, a core feature of typical misophonia triggers, the high misophonia participants did not find the beeps significantly more distracting than the control group. This reinforces the theory put forth by Swedo et al., (2022) that these negative responses do not seem to be elicited by general psychoacoustic features of a sound, such as loudness or pitch. This suggests that trigger sounds must be more about the salience and association of negative meanings with particular sounds, rather than the features of the sounds. This is supported by research done by Savard et al. (2022), in which participants with high and low traits of misophonia listened for a trigger sound in the presence of a masking sound. Both groups detected the trigger easily, however those with misophonia had a more intense reaction once they identified what the sound was. In our study, participants with misophonia not being any more affected by the beep track, further tells us that the auditory features of the sounds may not be the cause of strong, negative reactions for those with misophonia; but rather, it is the meaning that has been attached to them that is the cause of the aversive reaction.

Despite not finding any support for the hypotheses as it relates to misophonia, many interesting patterns emerged from the present study. The results of the study closely replicated the findings reported by Eerola and Vuoskoki (2010) in their investigation comparing discrete and dimensional models of emotion in music. One of their findings was that in the high examples, the target emotion was never confused with other emotion concepts, but the moderate examples exhibited confusion between one or two other concepts of emotion. Moderate tender excerpts were often mixed for happiness and/or sadness. Our findings show that moderate intensity happy excerpts had significantly lower categorization accuracy than all other emotion intensity categories. Interestingly, tender songs emerged as particularly challenging for participants to categorize correctly. This could further prove the general fuzziness in the definition of the emotion categories. Tender songs often encompass a blend of emotions that can include elements of both happiness and sadness, creating a nuanced and complex emotional experience. This amalgamation of emotions may make it difficult for listeners to categorize them accurately.

Our results also show that high intensity songs were categorized more easily than moderate intensity songs, corroborating the findings of Eerola and Vuoskoki (2010). As previously mentioned, fear songs were categorized more easily than happy, sad, and tender songs, and happy songs were categorized more easily than sad and tender songs. This pattern suggests that fear-inducing songs are more readily identifiable or distinguishable compared to songs conveying happiness, sadness, or tenderness. It implies that fear as an emotional state might have more distinctive and recognizable musical characteristics compared to other emotions like happiness, sadness, or tenderness. However, high intensity fear excerpts resulted in significantly reduced liking ratings, compared to moderate intensity fear. This finding indicates that there's an optimal level of arousal associated with fear-inducing stimuli. When fear is experienced at a moderate intensity, it may lead to higher liking ratings compared to when it is experienced at a high intensity. While some levels of fear can be enjoyable or pleasurable for individuals, excessively intense fear might lead to reduced enjoyment or liking. From a psychological perspective, this aligns with the construct of "optimal arousal," which Smith (1990) defines as a level of mental stimulation wherein physical performance, learning, or temporary feelings of wellbeing reach their peak. This implies that performance improves with physiological or mental arousal, but only to a certain extent. Beyond this optimal level of arousal, performance starts to decline. In the context of fear and liking ratings, it implies that there is a threshold beyond which fear becomes too intense, leading to negative evaluations. Understanding this optimal level of arousal for different emotions, such as fear, can be valuable in various fields, including entertainment, marketing, and psychology, as it can inform the creation of experiences that are engaging and enjoyable without becoming overwhelming or aversive.

Conclusion

To summarize, in a study involving 72 participants re-recruited from the main phase of a previous study (Babalola & Van Hedger, 2023), two sub-groups were formed based on their self-reports in a questionnaire designed for misophonia symptom assessment; a low misophonia group, largely unaffected by sound on their life and wellbeing, and a high misophonia group that exhibited heightened sensitivity to sound that affected their life and wellbeing. All participants engaged in a memory encoding task where they listened to and rated 16 musical clips spanning four emotions (happy, sad, tender, fear) and two intensities (moderate, high), fully crossed. This was followed by a beat alignment task and a melody recognition task where all participants rated

32 music clips for intensity, liking, categorization, and recognition confidence (old or new). Those with misophonia also had no significant differences in beat alignment performance compared to those without, despite the repetitiveness and expected distraction of the beeps. It was found that having misophonia did not have any impact on ratings overall. However, all participants found it difficult to categorize tender songs correctly. All participants also categorized moderate intensity happy songs with less accuracy than all other emotion intensity categories. Overall, high intensity songs were categorized with more ease than moderate intensity songs. Finally, high intensity fear excerpts were liked much less than moderate intensity fear excerpts, potentially due to optimal states of arousal. These results support the idea that misophonia has more to do with the attached meaning to sounds, rather than the auditory qualities. This can inform further research to focus on what those associations may be, and where they stem from. The results also highlight nuances in emotional categorization and preferences within musical stimuli, with potential implications for understanding emotional processing and arousal in individuals, including those with misophonia. This pattern of findings strongly supports those of Eerola and Vuoskoki's (2010).

The present study does have a few limitations. Beyond the limitations previously mentioned, the online study design sacrifices experimental control over listening contexts and sound quality that are possible with laboratory studies. The study also utilized a specific subset of emotional film soundtrack clips, which may not fully represent the diversity of emotional stimuli in real-world settings. While film music draws upon stereotypical conventions from both classical and more modern music and is very good at encompassing emotions - it is important to recognize that different results may emerge when considering other genres like pop or jazz. Additionally, a comprehensive analysis of the acoustical and musical characteristics of the stimuli is necessary to address key issues raised by the study, such as defining emotions and subtle distinctions in emotions like tenderness and sadness/happiness.

Our main goal was to explore misophonia as it relates to music and memory, hypothesizing that those with misophonia would have a better musical memory due to their increased emotional evocation while listening to music. Although this was not the case, we can envision future directions for research on misophonia as it relates to music. Future studies can aim to understand contexts where music might be better remembered for those with misophonia. It is known that music is often used to reduce/mediate negative reactions by providing a more positive auditory experience (Mednicoff et al., 2022). This means that in these contexts of trying to mediate and cope with trigger sounds, those with misophonia would pay more attention to music playing compared to those without. Perhaps in these more "naturalistic" contexts in which music is likely to invoke strong reactions and attention, we could see better memory for songs. The theory would be that music is masking trigger sounds, therefore they would be attended to more, and perhaps remembered better. Future research could use more ecologically valid methods to understand how music might be used in everyday experiences of someone with misophonia.

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