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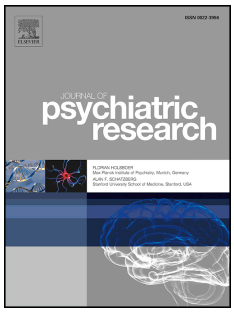

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Recognizing Individual Variability in Misophonia: Identifying Symptom-Based Subgroups with Gaussian Mixture Modeling

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Abstract

Misophonia is characterized by intense emotional and physiological reactions to everyday sounds such as chewing and tapping. While previous researchers have focused on defining and characterizing the disorder, limited attention has been given to the variability in symptom presentations across individuals. In this study, we sought to identify distinct subgroups of individuals with misophonia by applying a Gaussian finite mixture model to explore the heterogeneity of symptom profiles. Sixty treatment-seeking participants completed the Duke Misophonia Interview, which assessed the presence and severity of various behavioral, affective, and cognitive symptoms. Items from this measure served as model indicators. Two clusters were found: anticipatory and reactive. The anticipatory group reported heightened awareness of potential triggers, preemptive anticipatory distress, and increased avoidance behaviors, while the reactive group primarily displayed emotional and physiological responses during the occurrence of sounds. Notably, both groups reported similar frequencies of misophonic triggers, but the anticipatory group demonstrated greater internalizing symptoms, such as intrusive thoughts or rumination about misophonic sounds and social isolation. Our findings support the need for tailored interventions that address subgroup-specific symptom patterns. Future researchers should aim to include larger sample sizes and develop more comprehensive models to capture the full spectrum of misophonia symptoms, including externalizing behaviors.

Keywords: Misophonia, cluster analysis, internalizing symptoms, heterogeneity, sub-type

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The first scientific investigations of misophonia began just over a decade ago (e.g., Schroder et al., 2013). Psychologists, audiologists, and neurologists who have led the initial stages of this research have primarily focused on defining and characterizing the disorder. This research has led experts to classify misophonia as a sound sensitivity disorder, marked by intense emotional and physiological reactions to common sounds like chewing, breathing, and tapping (Swedo et al., 2022). The research thus far has consistently shown that misophonic reactions can severely impact relationships and are associated with significant difficulties in social, academic, and occupational functioning (Ferros-Terras et al., 2022; Brout et al., 2018). Additionally, misophonia can co-occur with psychiatric conditions such as generalized anxiety disorder and attention deficit hyperactivity disorder (Jager et al., 2020; Woolley et al., 2024). However, it is increasingly recognized that misophonia should be classified as a distinct disorder (Rosenthal et al., 2022; Swedo et al., 2022).

Despite key scientific advancements such as a set of proposed diagnostic criteria (Schröder et al., 2013; Jager et al., 2020), measurement tools, and treatment studies (see Mattson et al., 2023 for a review), individual variability in misophonia presentations remains underexplored, which has important implications for diagnosis and treatment. Notably, symptom severity appears to vary widely, particularly emotional responses to misophonic sounds. Some studies highlight a spectrum of emotional responses. For instance, emotional responses for those with moderate levels of misophonia typically involve more manageable experiences such as irritation and distress (Dibb et al., 2021; Tunç et al., 2017; Rouw & Erfanian, 2018). Alternatively, a substantial subset experience more intense reactions, escalating to panic, rage,

and in some cases, aggressive behaviors such as violence (Tunç et al., 2017; Guzick et al., 2023). Variability in physiological reactions has also been reported, ranging from muscle tension to headaches and physical pain (Wu et al., 2014; Rouw & Erfanian, 2018; Mednicoff et al., 2024).

Similarly, avoidance behaviors vary widely, from minimal strategies like covering the ears to more disruptive actions, such as avoiding family meals or certain individuals. The timing of avoidance differs as well; some individuals reactively avoid misophonic triggers in the moment, while others engage in anticipatory avoidance, taking preemptive steps to avoid situations where trigger sounds are expected (Guzick et al., 2023). Unsurprisingly, the extent of avoidance has been linked to the level of discomfort experienced when exposed to misophonic triggers (Claiborn et al., 2020). Furthermore, the intensity of misophonic symptoms is often associated with impairment and disruptions in quality of life (Möllmann et al., 2023; Guzick et al., 2023).

As research advances and diagnostic criteria for misophonia are refined (e.g., Swedo et al., 2022), the variability observed in the disorder suggests that it may be more appropriately understood dimensionally rather than categorically. While psychiatric diagnoses typically follow categorical frameworks, assessing symptoms on a spectrum provides a more nuanced understanding (Zimmerman et al., 2018). Moreover, diagnostic heterogeneity in psychiatry is not solely about differences in severity but also about how disorders manifest uniquely across individuals, depending on the presence of specific symptoms. For example, latent profile analysis has shown that individuals with severe and moderate depression exhibit distinct symptom patterns, with those experiencing severe depression reporting significantly higher levels of suicidal ideation and cognitive difficulties, such as problems with concentration and memory (Li et al., 2024). Similarly, studies of adults with post-traumatic stress symptoms

following natural disasters have identified four distinct profiles—minimal, low, moderate, and severe—where differences in avoidance, hyperarousal, and numbing play a critical role in distinguishing more severe presentations (Bondjers et al., 2018; Rosellini et al., 2014).

Recent efforts to understand the heterogeneity of misophonia have employed similar clustering techniques. For example, Norris et al. (2022) used k-means clustering to examine symptom presentations in a non-clinical sample, identifying subgroups with varying degrees of misophonia severity and associated conditions (e.g., tinnitus and sensory hypersensitivity). Similarly, McKay et al. (2018) applied Profile Analysis via Multidimensional Scaling to identify psychological symptom profiles, which highlighted different patterns associated with obsessive-compulsive features, interoceptive sensitivity, and distress tolerance. While these studies highlight the utility of clustering approaches for identifying broad symptom patterns of misophonia and its phenotypic features, these approaches have yet to classify individuals based on the specific behavioral, cognitive, and emotional processes involved in the disorder. Developing a more nuanced understanding of these mechanisms could advance classification systems, assessment tools, and interventions tailored to unique presentations of misophonia.

Recognizing the need to understand heterogeneity in the specific symptomatology of misophonia, researchers have begun examining the distinct symptom patterns that manifest differently among individuals with the disorder. For example, youth with misophonia experience varying levels of internalizing symptoms (e.g., anxiety, mood disturbances), which may be linked to isolation, rumination, and self-blame regarding their misophonic reactions. In contrast, externalizing symptoms (e.g., aggression, outbursts) were associated with overt dysregulated responses to trigger sounds and external blame (Armstrong et al., 2023). Although both symptom dimensions are related to misophonia

severity, they may manifest differently; one study showed for youth with misophonia, internalizing symptoms are linked to a lower quality of life whereas externalizing symptoms were not (Kook et al., 2024). Another study of adults found that more severe misophonia symptoms were associated with heightened anxiety or depressive emotions, rather than feelings of anger or annoyance, when exposed to triggering sounds (Möllmann et al., 2023). While these findings illustrate that individuals with misophonia may present with varying symptom profiles—ranging from internalizing to externalizing dimensions—there remains a need for more comprehensive measures that assess the full spectrum of emotional, behavioral, and physiological responses.

Currently, most existing measures of misophonia primarily assess symptom intensity and impairment (e.g., Wu et al., 2014; Siepsiak et al., 2020), with less focus on evaluating the full range of psychological, affective, and physiological responses that contribute to the complexity and heterogeneity of the disorder. To address this gap, Rosenthal et al. (2021) developed the Duke Misophonia Questionnaire (DMQ), which captures a broader range of internal and external behavioral, affective, physiological, and cognitive experiences. The DMQ later informed the development of the Duke Misophonia Interview (DMI; Guetta et al., 2022), a semi-structured interview designed to assess these facets in-depth through participant interviews and clinician ratings. This approach allows for the assessment of the presence and severity of unique psychological aspects of misophonia. Naturally, heterogeneity in symptomatology and intensity is revealed through individual-level item responses. Such person-specific variability in symptom endorsement holds significant implications for tailoring treatment, and the developers of these measures have emphasized the importance of flexible, person-centered interventions, such as the Unified Protocol and Process-Based Therapy (Rosenthal et al., 2023).

In the current study, we explored variability in misophonia symptoms by assessing whether distinct subgroups of individuals with misophonia can be identified. Using a model-based clustering approach, we utilized the behavioral, affective, and cognitive dimensions captured by the DMI as indicators to define these subgroups. Additionally, we examined the clinical relevance of these subgroups by comparing their levels of functional impairment, as well as comorbid psychological factors including stress, anxiety, and depression. The ultimate goal of this study was to enhance our understanding of potential differences in how misophonia presents and provide preliminary recommendations for more tailored intervention approaches.

Methods

Study Context

The present study includes data collected as part of a larger randomized controlled trial (RCT) evaluating a psychological intervention for misophonia (see MASKED FOR REVIEW). This study focuses exclusively on data collected during the initial assessment phase, prior to any intervention. All RCT procedures were preregistered on www.clinicaltrials.gov [INDENTIFER MASKED] and on the Open Science Framework: https://osf.io/9mwpd/?view_only=f7789c49dffe4a829cc6e504daac4bdc. The research was approved by a University Institutional Review Board.

Procedures

Recruitment and Eligibility Screening

The RCT was carried out in Utah, with participants recruited from within the state between November 2022 and November 2023. Participants were recruited through local advertisements and social media. Ads via Facebook and other platforms invited individuals interested in treatment for misophonia to participate in the study. Potential participants were

directed to an online screener that included the Misophonia Questionnaire (MQ; Wu et al., 2014). A total of 261 individuals completed the screener.

Participants qualified for an intake appointment to assess their eligibility for treatment if they scored above 5 on the severity item of the Misophonia Questionnaire (MQ; Wu et al., 2014), indicating at least mild impairment. Of the 261 individuals screened, 232 met this criterion and were invited to proceed to the next step. These individuals were contacted by email and invited to schedule a clinical intake interview. Of the contacted individuals, 75 consented and agreed to participate. The remaining individuals who were invited to participate did not respond to the invitation or declined to participate.

Baseline Procedures

All 75 of the consenting participants attended an intake appointment, which included a structured clinical interview for misophonia (the Duke Misophonia Interview; DMI; Guetta et al., 2022) to confirm the presence of misophonia and continued interest in receiving therapy for misophonia. The Diagnostic Interview for Anxiety, Mood, and Obsessive-Compulsive and Related Neuropsychiatric Disorders (DIAMOND; Tolin et al., 2018) was administered to assess comorbid diagnoses based on DSM-5 criteria (not reported in this paper [see MASKED FOR REVIEW]). The interview served to rule out any psychiatric conditions that would prevent misophonia from being identified as the primary condition requiring treatment. All interviews were conducted by a trained doctoral student in clinical psychology and supervised by the principal investigator, a licensed psychologist.

Additionally, the participants completed self-report questionnaires to provide information on their sociodemographic background, symptoms of misophonia, and other mental health variables. Finally, a doctoral student in audiology, under the supervision of an audiologist,

conducted an audiological evaluation to assess any peripheral hearing issues, such as hyperacusis or hearing loss. These audiological results were part of the broader clinical trial and are not examined in this paper (see [masked for review] for further details). Each participant received $60 as compensation for completing the clinical interview and the self-report questionnaire.

After completing the initial intake appointment, participants were deemed eligible for the study if they scored a total score of 20 or greater on the Duke Misophonia Interview (DMI; Guetta et al., 2020). This score was pre-selected as a cutoff to mark clinically significant levels of misophonic symptoms, as it falls one standard deviation below the norm established by the measure's validation sample. This score was used as a clinical cutoff to ensure that participants' symptoms were sufficiently severe to warrant intervention. Following the administration of the DMI, during which misophonia symptoms and their functional impact were discussed, participants were asked to confirm their continued interest in pursuing therapy to ensure the sample consisted of individuals actively seeking treatment. A total of 15 participants were excluded from the final sample for the following reasons: nine individuals scored below the established cut-off on the DMI, two had sound sensitivities related to trauma, one participant had sound sensitivities primarily due to volume, one participant met criteria for a current manic episode (which represented a primary presenting problem over misophonia), and two participants decided they no longer wished to pursue treatment for misophonia.

Sample Characteristics

The final sample included 60 treatment seeking participants with misophonia who primarily self-identified as White (98.3%), non-Hispanic (96.7%), heterosexual (76.7%), women (90.0%), with an average age of 33.80 years (*SD* = 12.18); see Table 1 for all participant demographics.

Measures

Duke Misophonia Interview (DMI; Rosenthal et al., 2021; Guetta et al., 2022)

The Duke Misophonia Interview (DMI) is an 18-item semi-structured clinical interview designed to assess both the presence and severity of misophonia symptoms. The DMI evaluates trigger sounds, reaction severity, and functional impairment, focusing on both current symptoms and symptoms experienced over the participant's lifetime.

Items 2 through 14 of the DMI assess a range of specific internalizing and externalizing cognitive, behavioral, and emotional symptoms associated with misophonia (e.g., the experience of negative emotions during a misophonic trigger, as evaluated in Item 6). These items capture the presence, frequency, and intensity of symptoms. Symptom severity over the past month is rated using a 5-point Likert scale, and these ratings are combined to generate a current severity score. When a symptom is present, its perceived impact on functioning is assessed, contributing to a "current impairment" subscale. Global levels of impairment are assessed separately using items 15 to 18, which focus on the broader impact of misophonia symptoms on daily functioning, such as relationships with family, friends, and colleagues (e.g., Item 15).

For the current study, only the severity scores from the current severity subscale were used as indicators in model-based clustering to identify distinct subgroups based on misophonia symptoms. The global impairment subscale, rather than the current impairment subscale, was selected to assess functional impairment in this study. This decision was made because the current impairment items are only administered when a symptom is present, leading to overlap between impairment and severity that would complicate subgroup comparisons in the clustering analysis.

The DMI has demonstrated excellent preliminary psychometric properties, including strong internal consistency, predictive validity, and test-retest reliability (Guetta et al., 2022), making it a reliable and valid instrument for clinical assessment of misophonia. While formal interrater reliability testing was not assessed, the doctoral student interviewer and the principal investigator (a licensed psychologist) reviewed interview recordings for the first ten participants together. This process ensured agreement on item scoring, enhancing the consistency and accuracy of the assessments. The reliability of the global impairment subscale in this study was acceptable (α = .68).

Misophonia Questionnaire (MQ; Wu et al., 2014)

The Misophonia Questionnaire (MQ; Wu et al., 2014) is a self-report instrument consisting of 18 items that measure various aspects of misophonia, including severity and the specific nature of symptoms. It contains three subscales; the first subscale (7 items) assesses the presence of misophonia-related symptoms, while the second (10 items) focuses on the emotional and behavioral responses to misophonic triggers. The final subscale is a single-item measure of overall symptom severity. For the symptoms subscale, participants rate their sensitivity to specific sounds (such as repetitive tapping or eating noises) on a 5-point Likert scale, ranging from 0 (*not at all true*) to 4 (*always true*). Similarly, the emotional and behavioral responsivity subscale evaluates participants' reactions (e.g., leaving the area, feeling irritated), also on a 5-point scale, from 0 (*never*) to 4 (*always*).

The total MQ score, calculated by summing the scores from the symptoms and emotional/behavioral subscales, ranges from 0 to 68, with higher scores indicating greater symptom severity. Additionally, the single-item severity scale captures the overall intensity of misophonia on a scale from 1 (*minimal*) to 15 (*very severe*), where scores of higher than 6

suggest clinically significant levels of impairment. In this sample, the MQ demonstrated acceptable internal consistency ($\alpha = 0.74$).

The Depression Anxiety Stress Scale-21 (DASS-21; Lovibond & Lovibond, 1995).

The DASS-21 is a 21-item self-report questionnaire that evaluates levels of emotional distress in three areas: depression, anxiety, and stress. Each subscale contains seven items. Participants are asked to rate how often they experience specific symptoms on a 4-point Likert scale, ranging from 0 (*never*) to 3 (*almost always*). The scores for each subscale are summed and then doubled, with higher scores indicating greater levels of distress. The DASS-21 has shown strong psychometric properties, including good validity and reliability (Henry & Crawford, 2005). In the current sample, the internal consistency of the subscales ranged from .81 to .93.

Statistical Analysis

Software and Preprocessing

All statistical analyses were conducted using R version 4.4.1 (R Core Team, 2024), specifically utilizing the *mclust* package (Scrucca & Raftery, 2018). Preprocessing of the data revealed no item-level missingness across the measures used in this study. Transparent and reproducible code for all analyses can be found on the Open Science Framework: https://osf.io/ytd3a/?view_only=160f09b399b34050a2c5098faa0a5953.

Model-Based Clustering

To assess heterogeneity in misophonia symptom presentations, a Gaussian finite mixture model was employed to identify distinct subgroups within the sample. Symptom profiles were constructed using items 3 through 13 of the DMI. Item 14, which addresses self-destructive behavior (i.e., self-harm) to cope with misophonia, was not included in the model due to its low endorsement ($n = 3$).

This clustering approach assumes that the data consist of several Gaussian distributions, each representing a distinct subgroup. We selected the Gaussian mixture modeling (GMM) approach due to its flexibility in modeling different covariance structures and its ability to handle complex, multivariate relationships. This flexibility allows for more accurate identification of clusters based on symptom profiles, an essential consideration given the exploratory nature of the study and the relatively small sample size. Unlike latent profile analysis, which assumes equal variances within clusters (Vermunt, 2002), GMM accommodates variations in the shape, size, and orientation of clusters. As this is the first study to examine misophonia subgroups based on cognitive, emotional, and behavioral indicators of misophonia as measured by the DMI, GMM provided the necessary flexibility to capture the complexity of symptom relationships.

Model selection was guided by the Bayesian Information Criterion (BIC) and the Integrated Complete-data Likelihood (ICL) criterion (Baudry et al., 2010), with lower values indicating better-fitting models. Uncertainty of group assignment was assessed to ensure that participants were assigned to the most appropriate group with high confidence. The process began with a two-group solution, incrementally increasing the number of groups until the optimal solution was identified.

Clinical Comparisons

Once the best-fitting model was selected, further between-group comparisons were conducted to assess differences in relevant clinical measures, including misophonia symptoms as measured by MQ subscale and misophonia related impairment using the DMI global impairment score. Additionally, groups were compared on measures of stress, anxiety, and depression as assessed by the DASS-21. Shapiro-Wilk's tests were performed for each measure to determine

whether scores were normally distributed. When the assumption of normality was violated, Mann-Whitney U tests were used for comparison.

Results

Model-Based Cluster Analysis

The model-based cluster analysis (see Figure 1 for models with BIC values) initially identified an equal volume and shape (EEI) model with two classes as a viable solution. The two-class model showed good fit based on BIC (-1751.64) and ICL (-1758.18) values. Furthermore, the bootstrap likelihood ratio test indicated that the improvement from one class to two classes was significant (p = .001). Uncertainty tests for the two-class model demonstrated high certainty in class assignments, with average posterior probabilities of 0.94 for class one (n = 31) and 0.97 for class two (n = 29), indicating high certainty in class assignments based on the two-class model.

Although the two-class model showed good fit, a three-class solution was also considered based on its BIC (-1755.90) and ICL (-1760.16) values, which were similarly strong. The bootstrap likelihood ratio test confirmed that the improvement from two to three classes was significant (p = .001), although the improvement from three to four classes was not significant (p = .055), suggesting that a three-class model could also be a viable solution. Moreover, uncertainty tests for the three-class model revealed average posterior probabilities were 0.96 for class one (n = 18), 0.97 for class two (n = 25), and 0.98 for class three (n = 17), demonstrating reliable group assignment, albeit with slightly lower certainty for the third class.

Model Selection

Given that the two-class and three-class models fit the data well, a data-driven approach was employed to determine which model provided a better fit. Comparisons were made between

the two groups in the two-class solution and the three groups in the three-class solution, using MQ severity and DMI global impairment scores. These comparisons were conducted to evaluate which model more effectively distinguished unique classes of individuals with misophonia. Mann-Whitney U tests were performed for the two-class comparison, while analysis of variance (ANOVA) was performed to examine differences across the three-class group solutions.

In the two-class model, group two scored significantly higher than group one on the MQ emotional and behavioral responses to trigger sounds (Cohen's $d = 0.68$, $p = .032$), MQ severity ($d = 0.79$, $p = .012$), and DMI global impairment ($d = 1.13$, $p = .001$), identifying group two as more severe and impaired. In contrast, the three-class model showed no significant differences across the groups for MQ misophonia symptoms, MQ severity, or MQ emotional and behavioral reactions (ps < .084). However, a between groups effect was observed for DMI global impairment ($F(2, 57) = 5.284$, $p = .008$), but post-hoc Tukey's Honestly Significant Difference test revealed that these differences were only significant between classes one and two (*diff* = 1.93, $p = .007$), but not between classes one and two or classes two and three. Due to the clearer group distinctions in severity and impairment in the two-class model, it was selected as the most optimal solution. As a result, we did not interpret the three-class solution further, but between-group comparisons for the DMI model indicators in the three-class solution can be found in the supplemental material (see Table S1).

Model-Based Cluster Analysis: Group Interpretation

The two clusters were a *reactive* group ($n = 31$), who have fewer misophonia symptoms and predominately react to misophonic triggers only when they occur, and an *anticipatory* group ($n = 29$), who have more symptoms, heightened vigilance, and increased anticipation of triggers. The anticipatory group scored significantly higher than the reactive group on the majority of

DMI symptoms, with moderate to large effect sizes (see Table 2 for details), indicating a more severe or symptomatic presentation of misophonia.

The most pronounced symptom differences between the anticipatory and reactive groups were observed for negative emotions before triggers (d = 2.64) and hypervigilance for misophonic triggers (d = 1.76). These results suggest that the anticipatory group experienced higher levels of preemptive internalizing symptoms, such as anticipatory distress and heightened emotional responses even before triggers occurred, whereas the reactive group exhibited fewer signs of pre-emptive misophonic distress or vigilance towards the possible misophonic triggers. This distinction is further illustrated in Figure 2, which shows plotted means for each subgroup across all items in the model.

Additional notable differences emerged between the groups, with the anticipatory group reporting significantly higher levels of intrusive thoughts or rumination about prior misophonic experiences (d = 1.38) and a stronger sense of being misunderstood or detached from others due to their symptoms (d = 1.72). These findings highlight the anticipatory group's tendency toward more persistent internalizing symptoms. Moreover, the anticipatory group reported greater engagement in deliberate avoidance of situations where they might encounter triggering sounds (d = 1.00).

Despite these differences, both groups displayed similarly high scores for the need or desire to escape from triggering situations, physiological reactions to misophonic triggers, and negative thoughts during such events. These symptoms were reported at moderate to severe levels across both groups. However, the anticipatory group reported significantly higher scores on these reactive symptoms, suggesting that for the anticipatory group these symptoms may be more intense (ds = 0.88-1.01).

Interestingly, no significant group differences were found in negative emotions after misophonic sounds or verbal or physical aggression in response to triggers (*p*s > .05). This indicates that both subgroups exhibited similar emotional and behavioral responses during and immediately following misophonic triggers, reflecting shared externalizing reactions in the moment. However, more pronounced distinctions were evident when triggers were absent, with the anticipatory group displaying more pronounced internalizing symptoms, such as hypervigilance, anticipatory anxiety, and persistent distress outside of the triggering situations.

Clinical Comparisons

Finally, we compared the two groups on relevant clinical variables (see Table 3). No significant differences were found between the groups in terms of anxiety symptoms, with both groups reporting average anxiety levels within the normal range based on clinical cutoff scores for the DASS-21. Similarly, there were no significant differences in depressive symptoms, though it is worth noting that on average the reactive group endorsed little to no depressive symptoms (normal range), while the anticipatory group reported mild depressive symptoms. In contrast, the anticipatory group reported significantly higher levels of stress, though the effect size was modest ($d = 0.64$). The reactive group scored within the normal range for stress, while the anticipatory group's scores met the criteria for mild levels of stress.

Discussion

In this study, we investigated variability in misophonia symptom profiles by employing a model-based clustering approach to identify distinct subgroups. A two-class model, which nearly evenly divided the sample, provided the best fit for the data, differentiating participants into anticipatory and reactive subgroups. Using this model, we successfully distinguished subgroups based on the severity and impairment of misophonia symptoms, with the anticipatory group

reporting more severe symptoms and greater impairment. While previous researchers have acknowledged heterogeneity in misophonia symptomatology (e.g., Armstrong et al., 2023; Guzick et al., 2023), this study is the first to distinguish subgroups of individuals based on unique cognitive, emotional, and behavioral symptoms specific to misophonia using a clustering approach.

The anticipatory group was characterized by heightened awareness of potential triggers, even when misophonic sounds were absent. These individuals demonstrated increased preemptive anticipation and vigilance toward triggers, which could explain why avoidance was also more elevated among this group. In contrast, participants in the reactive group displayed elevated emotional and physiological reactions primarily when the sounds were occurring.

Interestingly, there were no significant differences between the groups in terms of the MQ symptom subscale, which measures the frequency of misophonic triggers. This suggests that both groups may experience a similar number of triggers, leading to questions about why the anticipatory group exhibits greater levels of behavioral and emotional reactions to the sounds and impairment. One possibility is that the anticipatory group's heightened vigilance consumes more cognitive and emotional resources, intensifying their overall experience of misophonia. This theory aligns with the concept of experiential avoidance, where individuals attempt to control or avoid intense emotional reactions, leading to increased preoccupation with potential triggers (Cowan et al., 2022). This may explain why the anticipatory group is more consumed by anticipatory anxiety and hypervigilance, whereas the reactive group predominately displays negative cognitive, emotional, and physiological reaction to sounds when they occur. To fully understand how symptoms interact and maintain misophonia in these subgroups, researchers

could apply network modeling to explore the unique symptom interactions that drive the disorder in each group.

Both subgroups reported moderate to severe negative cognitive, emotional, and physiological reactions to misophonic sounds, though these symptoms were more intense in the anticipatory group. This finding suggests that stress responses to misophonic sounds may be common across different presentations of the disorder, regardless of severity. Interestingly, there was no significant difference between the groups in emotional reactions after the sounds had stopped, suggesting that the in-the-moment stress responses are substantial enough to linger, making recovery more difficult for both groups.

The anticipatory group reported significantly more internalizing symptoms, such as intrusive thoughts, rumination about prior misophonic sounds, and feelings of social isolation. Historically, misophonia was thought to be characterized by externalizing behaviors, such as rageful outbursts (Vitoratou et al., 2021; Jager et al., 2020). However, our findings, along with more recent research (Guizick et al., 2023; Spencer et al., 2023), suggest that misophonia is more closely associated with internalizing symptoms. This shift in understanding aligns with findings from Kook et al. (2024) and Vitoratou et al. (2021), which link misophonia severity to internalizing forms of distress.

While the externalizing dimension of misophonia was assessed through verbal or physical aggressive reactions, both groups reported moderate levels of aggression, with no significant differences between them. This suggests that externalizing symptoms, such as aggression, may be a more universal symptom dimension in adults, regardless of the severity of the disorder. However, the DMI item assessing aggression also captures the distress individuals feel about their reactions, revealing that this item might reflect internalizing (e.g., guilt or regret)

and externalizing (e.g., aggressive behavior) dimensions of misophonia. This complexity makes it challenging to distinctly identify externalizing symptoms using the DMI. Therefore, researchers should explore variability on externalizing symptoms in adults with misophonia.

In comparing other clinical measures between the groups, the anticipatory subgroup reported significantly higher levels of general stress, as expected, given their tendency to be more overwhelmed by misophonic symptoms. Surprisingly, both groups reported similar levels of anxiety and depression, which may seem unexpected given the association of mood and anxiety symptoms with internalizing forms of psychopathology. However, while the overall means for anxiety, depression, stress symptoms on the DASS-21 were in the normal to mild range, prior research has documented similar patterns in misophonia samples (e.g., Wu et al., 2014; Ghorbani et al., 2022). This suggests that our sample may not be entirely atypical in this regard and reflects the variability commonly observed in psychological distress and comorbidity rates among individuals with misophonia (Rosenthal et al., 2022; Jager et al., 2020). Still, the generally mild levels of symptoms in the sample may have contributed to the absence of significant group differences for depression and anxiety, despite their established associations with misophonia severity (Almadani et al., 2024).

Overall, our findings support the need for a more individualized approach to treatment in misophonia. For the anticipatory group, interventions that focus on internalizing symptoms, such as addressing anticipatory anxiety and intrusive thoughts and rumination, may be particularly beneficial. Cognitive skills that help address internalizing appraisals such as self-blame or mindfulness-based strategies to manage hypervigilance could be effective in this group. For the reactive group, treatments may need to focus more on managing in-the-moment emotional and physiological reactions to misophonic sounds. This may include teaching emotion regulation

strategies or relaxation practices that can be used in moments of heighten distress when the sounds themselves are occurring.

Leveraging symptom profiles to guide clinical decision-making may represent a promising avenue for treatment development in misophonia. For example, the Personalized Advantage Index (PAI; DeRubeis et al., 2014) demonstrates the potential of predictive modeling to allocate individuals to treatments likely to yield the greatest benefit. For misophonia, predictive algorithms could be developed to assign individuals to targeted interventions based on their symptom profiles. However, a challenge lies in the tendency to impose binary or categorical classifications when assigning treatments, which may fail to capture the full complexity of individual differences. Furthermore, strict algorithmic prediction models often reflect the constraints of the samples they are based on (van Bronswijk, 2024) and invite ongoing debate about the utility of actuarial methods compared to clinical judgment, as proposed by Meehl (1954) in his seminal work. As algorithm-based clinical decision-making evolves (see Deisenhofer et al., 2024, for a discussion), future research may revisit the implications of the subgroups identified in the current study within a binary or catagorical treatment matching framework.

For now, researchers are increasingly recognizing the value of therapy protocols that can be flexibly adapted to meet the unique needs of individuals with misophonia (Rosenthal et al., 2023; Mattson et al., 2023). Approaches like the Unified Protocol allow for the selection and delivery of various cognitive and behavioral intervention modules based on the individual's presenting symptoms (Barlow et al., 2011). Similarly, process-based therapy tailors treatment components to target the processes of change most relevant to the individual (Hofmann et al., 2022). These interventions are actively being tested in clinical trials to address misophonia

symptoms (see Rosenthal et al., 2023). Our findings contribute to the growing body of literature suggesting that a one-size-fits-all treatment model may be insufficient given the diverse ways in which individuals with misophonia present to treatment. To support this tailored approach, tools that assess the spectrum of misophonic symptoms each individual experiences are essential for guiding case formulation. The DMI appears to be a valuable resource for understanding symptom variability in misophonia, helping clinicians personalize interventions to address the specific needs of each patient.

Our results should be considered in light of several limitations. Firstly, the DMI is a clinician-rated interview, and interrater reliability was not assessed, which limits the ability to ensure that DMI scoring is replicable across different raters or settings. Current research using the DMI has yet to report interrater reliability (see Guetta et al., 2022), highlighting the need for future studies to establish this metric. Additionally, while diagnostic criteria for misophonia have been proposed (Jager et al., 2020; Swedo et al., 2022) and validated screening measures exist (Williams et al., 2022), these were not used as inclusion criteria in this study. However, participants were recruited into the parent trial based on their perceived need for treatment due to the intensity of their symptoms, suggesting a clinically relevant misophonia sample.

Another limitation is the sociodemographic homogeneity of our sample, reflecting Utah's population, where 22.3% identify as non-White or Hispanic, which is significantly lower than national averages (U.S. Department of Health and Human Services, 2024). Utah's unique cultural and geographic factors further shape its demographics. Future research should prioritize nationally representative samples to validate these subgroups both across the United States and globally.

Finally, a sample size of 60 poses limitations, as GMM and cluster-based approaches are highly data-driven and sensitive to the selected sample. Future studies should replicate this work in larger and more diverse samples to determine whether these clusters remain consistent or if alternative models, such as a three-group solution, better capture the variability in misophonia presentations. That being said, while our data supported a two-class solution, our findings also suggested additional subgroups may exist. Future research should also explore whether these clusters can be replicated using different person-centered methodologies, such as LCA or LPA, which may provide a complementary perspective on subgroup variability.

It should also be noted that the identified subgroups are not entirely homogeneous, as GMM is a variable-centered modeling approach rather than a person-centered one, as seen in other clustering techniques. Consequently, variability within each identified group is expected and should be considered when designing interventions and conducting future research. This within-group variation highlights the importance of tailoring treatments to individual needs, even within distinct subgroups.

Despite limitations, the current study contributes to the growing understanding of misophonia by identifying distinct subgroups within individuals based on symptom profiles, using GMM. The two-class model differentiated participants into anticipatory and reactive subgroups, revealing important differences in symptom severity, internalizing symptoms, and functional impairments. These findings underscore the need for tailored treatment approaches that address the unique symptom constellations within each group. Specifically, anticipatory individuals may benefit from interventions targeting anticipatory anxiety and rumination, while reactive individuals may require strategies for managing immediate emotional and physiological reactions to triggers. The results also suggest that misophonia may be best understood as a

dimensional disorder, with varying degrees of severity and symptom presentations across individuals. Looking ahead, researchers should aim to use larger samples to investigate symptom interactions and explore the potential existence of other unique subgroups. These efforts will be essential for refining our understanding of misophonia and enhancing personalized treatment strategies for misophonia.

Declaration of generative AI and AI-assisted technologies in the writing process:

During the preparation of this work the authors used ChatGPT 4.o in order to improve the clearity and readibility of the introduction and discussion sections. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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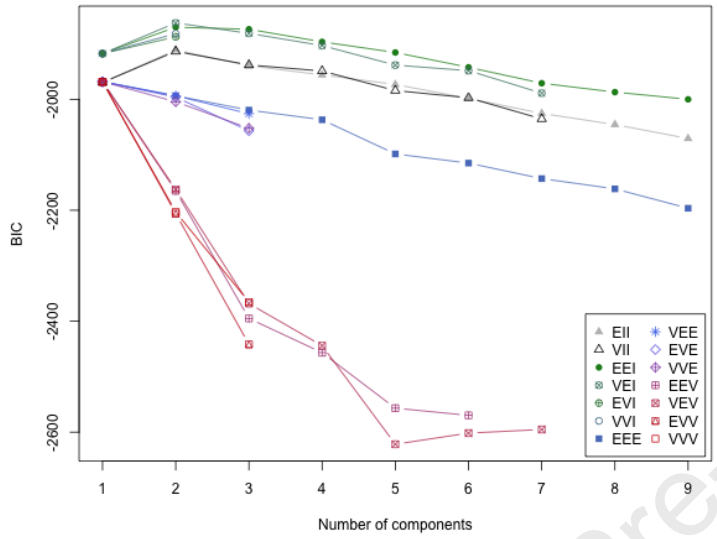
Figure 1

Bayesian Information Criterion (BIC) for Different Cluster Solutions



Note. BIC = Bayesian Information Criterion; EII = equal volume, round shape (spherical covariance); VII = varying volume, round shape (spherical covariance); EEI = equal volume, equal shape, axis parallel orientation (diagonal covariance); VEI = varying volume, equal shape, axis parallel orientation (diagonal covariance); EVI: equal volume, varying shape, axis parallel orientation (diagonal covariance); VVI = varying volume, varying shape, equal orientation (diagonal covariance); EEE = equal volume, equal shape, equal orientation (ellipsoidal covariance); VEE = varying volume, equal shape, equal orientation (ellipsoidal covariance); EVE = equal volume, varying shape, equal orientation (ellipsoidal covariance); VVE = varying volume, varying shape, equal orientation (ellipsoidal covariance); EEV = equal volume, equal shape, varying orientation (ellipsoidal covariance); VEV = varying volume, equal shape, varying orientation, (ellipsoidal covariance); EVV = equal volume, varying shape, varying orientation (ellipsoidal covariance) VVV = varying volume, varying shape, varying orientation (ellipsoidal covariance).

Figure 2

Plot of Two-Class Model Misophonia Duke Misophonia Interview Symptom Clusters

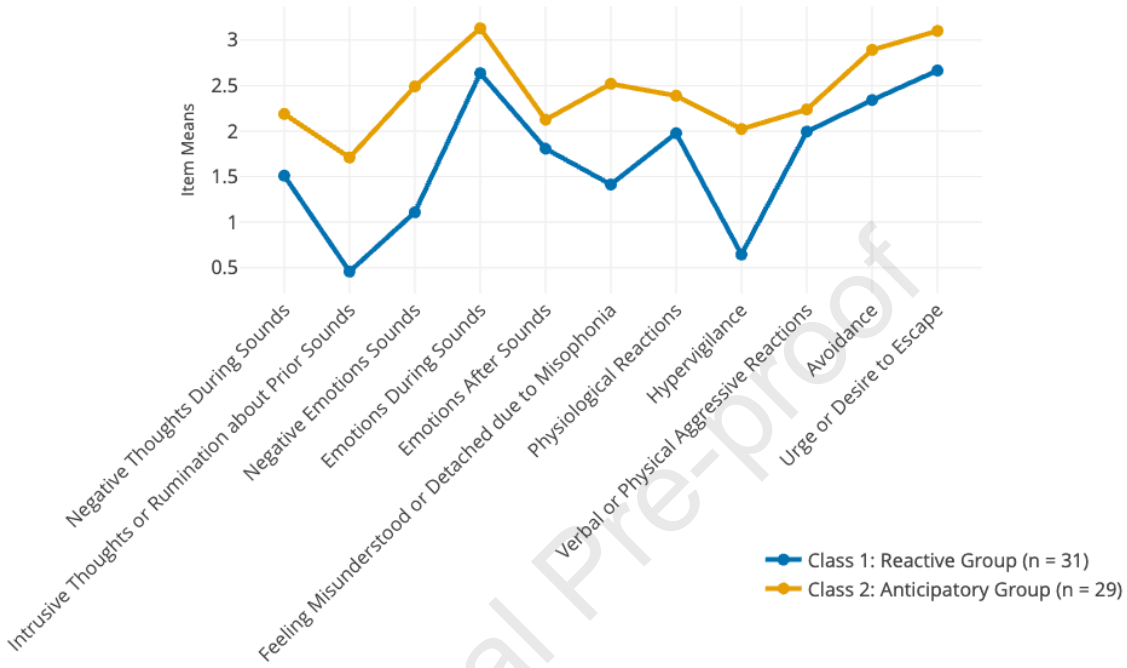


Table 1

Participant Sociodemographic Information (N = 60)

	n (%)
Gender Identity	
Woman	42 (70)
Man	14 (23.3)
Non-Binary	3 (5)
Agender	1(1.7)
Sexual Orientation	
Asexual	3 (5)
Bisexual	4 (6.7)
Heterosexual or straight	46 (76.7)
Pansexual	5 (8.3)
Queer	2 (3.3)
Ethnicity	
Hispanic or Latino	2 (3.3)
Race and Ethnicity[1]	
Asian or Asian American	2 (3.3)
Black or African American	1 (1.7)
Native South American	1 (1.7)
White or White American	59 (98.3)
Religion	
Church of Jesus Christ of Latter-Day Saints	27 (45)
Jewish	1 (1.7)
Not Religious	27 (45)
Other	5 (8.3)
Marital Status	
Divorced	3 (5)
Living with a partner	5 (8.3)
Married	34 (56.7)
Single	18 (30)
Employment Status	
Employed full-time	26 (43)
Employed part-time	17 (28.3)
Retired	2 (3.3)
Student	10 (16.7)
Unemployed	2 (3.3)
Other	2 (3.3)
	***M* (*SD*)**
Age (years)	33.80 (12.18) Range = 18-67

[1]Categories not mutually exclusive.

Table 2

Comparison of Two-Class Model Clusters on Duke Misophonia Interview Symptoms

Duke Misophonia Interview Items	**Reactive Group M (SD)**	**Anticipatory Group M (SD)**	***U***	***p***	**Cohen's *d***
Negative thoughts during misophonic triggers.	1.45 (1.03)	2.28 (1.00)	242	<.001**	1.04
Intrusive thoughts or rumination about prior misophonic sounds	0.55 (0.89)	1.66 (0.97)	194	<.001**	1.38
Negative emotions before trigger sounds.	1.13 (0.85)	2.52 (0.51)	91	<.001**	2.64
Negative emotions during misophonic sounds.	2.65 (0.55)	3.14 (0.35)	252	<.001**	0.98
Negative emotions after misophonic sounds.	1.84 (0.97)	2.10 (0.94)	375	0.242	0.34
Feeling misunderstood or detached from others due to misophonia.	1.39 (1.02)	2.59 (0.73)	156.5	<.001**	1.72
Physiological reactions to misophonic triggers.	1.90 (0.75)	2.48 (0.87)	269	.004**	0.88
Hypervigilance for misophonic triggers.	0.61 (0.80)	2.10 (1.18)	153	<.001**	1.76
Verbal or physical aggression in response to sounds.	2.00 (1.13)	2.24 (0.99)	408.5	.520	0.18
Deliberate efforts to avoid situations, people, places.	2.35 (0.61)	2.90 (0.49)	248	<.001**	1.00
Need or desire to escape from triggering situations.	2.71 (0.64)	3.07 (0.53)	323	.025*	0.59

Note. ** p < .01, * p < .05.

Table 3

Comparison of Two-Class Model Clusters on Relevant Clinical Measures

Clinical Variables	Full Sample *M* (SD)	Reactive Group *M* (*SD*)	Anticipatory Group *M* (*SD*)	*U*	*p*	Cohen's *d*
Misophonia Questionnaire (MQ) Subscales						
Symptoms	16.90 (5.12)	16.52 (5.14)	17.3 (15.16)	412.5	.588	0.17
Emotional and Behavioral Responsivity	21.90 (4.94)	19.84 (4.73)	22.55 (4.84)	304.5	.032*	0.68
Severity	6.83 (1.68)	6.32 (1.78)	7.38 (1.40)	283.5	.012*	0.79
Duke Misophonia Interview (DMI) Global Impairment	8.90 (1.92)	8.16 (1.88)	9.69 (1.65)	228.5	<.001**	1.13
Depression Anxiety Stress Scale-21 (DASS21)						
Depression	10.03 (10.87)	8.13 (8.87)	12.07 (12.52)	367.5	.224	0.37
Anxiety	6.33 (7.38)	5.10 (5.13)	7.66 (9.10)	392	.393	0.26
Stress	14.30 (8.52)	12.00 (7.85)	16.76 (12.52)	313	.043*	0.64

Note. ** p < .01, * p < .05.

Authors have no conflicts of interest to declare.