Research Article

Do Individuals with Misophonia Experience Challenges with Their Auditory Binaural Interaction and Integration Skills?

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Highlights

- DCV and Masking level difference were measured in mild and moderate misophonia
- Binaural integration and interaction skills are unaffected in misophonia

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ABSTRACT

Background and Aim: Misophonia is a condition marked by heightened sensitivity and intense emotional and physiological responses to particular sounds that may not spark the same reactions in others. This study is the first of its kind to assess binaural integration and binaural interaction in misophonia.

Methods: Thirty misophonia and 30 control participants were considered in the age range of 18 to 30 years. All the participants had hearing sensitivity within normal limits and normal middle ear function. Individuals with a history of otological complaints, noise exposure, ototoxic medications, tinnitus, hyperacusis, diabetes, or hypertension were excluded from the study. Misophonia severity was assessed using the Misophonia Assessment Questionnaire (MAQ). Binaural integration was assessed using Dichotic Consonant Vowel (DCV) test, and binaural interaction was assessed using Masking Level Difference (MLD).

Results: The statistical analysis of the independent t-test for DCV and Mann Whitney U test for MLD showed no significant difference between misophonia and the control group for both MLD and DCV.

Conclusion: The results suggest that there is no significant difference in DCV and MLD scores between the control and misophonia groups.

Keywords: Misophonia; binaural integration; binaural interaction; dichotic consonant vowel; masking level difference

Introduction

Misophonia is a disorder characterized by negative physiological or emotional reactions in response to particular sounds that do not cause annoyance [1] Schröder et al. [2] proposed diagnostic criteria for misophonia, including extreme behavioral or physiological response to the presence or anticipation of certain sounds, anger, loss of self-control, and avoidance of misophonic sound situations. In other words, misophonia is hatred or decreased tolerance to particular sounds that may be normal for others. The reactions to the sound depend on the physical properties of the sound and the environment in which it is presented. Triggering sounds could be chewing, metal scraping, high-frequency insect chirping, etc. [2-5]. The reactions to triggering sounds could be anger, irritation, increased heart rate, sweating, anxiety, etc. Neuroimaging studies showed cortical generators involved in misophonia generation. Hyperactivation of the right insula, right anterior angulate cortex, and right superior temporal cortex was seen when misophonic individuals were exposed to triggering audiovisual input compared to neutral video clips [6, 7] In addition, Aryal and Prabhu [8] proposed a neurobiological model of Misophonia generation, where they hint at the central auditory involvement in addition to the other cortical areas (such as those involved in emotion or psychological distress).

Central Auditory Processing (CAP) is the ability to perceptually receive stimuli within the Central Auditory Nervous System (CANS) and conduct the subsequent neurobiological activities that give rise to the electrophysiological auditory action potentials [9]. Auditory processing includes temporal processing, binaural interaction, fusion, integration, separation, and auditory closure. Binaural integration is when the patient has to repeat stimuli in both ears [9]. Difficulties faced by individuals with binaural integration deficits include having trouble taking notes, processing more than one modality concurrently, or listening to two persons simultaneously. Binaural interaction refers to the task where the CANS interprets stimuli presented simultaneously to both ears [10]. This process occurs at the brainstem level, where information from both ears is processed.

Conventionally, binaural interaction is assessed through Masking Level Difference (MLD), while binaural integration abilities are measured using the Dichotic Consonant Vowel (DCV) test [11]. MLD describes how the phase of either the signal or the noise at the two ears can be changed to improve the perception of a signal when a masker is present [12]. ‘o’ indicates when the signal is in phase and ‘π’ indicates when signal is out of phase. SoNo is a homophasic condition where signal and noise are in phase and SπNo and SoNπ are antiphasic conditions where one of the signals is out of phase. In the case of SπNo, the signal is out of phase, and in SoNπ, the noise is out of phase. SπNo and SoNπ are easier to detect compared to SoNo, which shows that antiphasic conditions are easier to detect compared to homophasic condition. When the signal and noise are in phase, the auditory image is perceived at the central location of the head. The signal or noise phase shift leads to a separation between them, which facilitates easy detection. Conversely, the DCV test assesses the binaural integration ability and is more complex than other dichotic speech tests. The stimuli used in DCV are pairs of pa, ta, ka, ba, da, ga. Two distinct CVs are presented simultaneously to both ears and the subject has to repeat. Right single correct score, left single correct score, and double correct score are calculated. DCV test is sensitive to cortical lesions. However, its ability to detect cortical lesions’ lateralization (right or left cortical regions) is limited.

The evaluation of the CANS in individuals with misophonia is still unexplored. Out of the explored processes, Ilaa et al., studied temporal auditory processing in individuals with misophonia using gap-in-noise, duration pattern, and frequency pattern tests [13]. The results of their study showed no group differences. To the authors’ knowledge, no study has yet explored the binaural interaction and integration in misophonics. However, literature evidence on the binaural deficits in the tinnitus individuals is available. It has been reported that binaural processing and working memory ability are affected in individuals with tinnitus [14]. The pathway involved in tinnitus and misophonia is similar [8, 15]. There is abnormal activation of the non-classical auditory pathway in both conditions. The trigger is perceived in the peripheral auditory system, which is then connected to the subcortical and cortical auditory centers. Whereas in tinnitus, the trigger is substituted with an external

source and the rest of the path follows the same as tinnitus. There have been studies where the authors have reported binaural interaction deficits in individuals with tinnitus [16]. Another study on tinnitus individuals showed abnormal results on central auditory speech tests, including pass filtered speech test, staggered spondaic word test, binaural fusion test, and competing sentence test [17]. According to neuroaudiological model, misophonia and tinnitus have similar pathophysiology so one can expect similar findings in misophonia. There is research evidence that shows abnormal results in auditory objective tests such as significant differences in P1 and N1 latency peaks in late latency response test which indicates deficit in cortical auditory processing and reduced N1 amplitude in mismatch negativity test [18, 19]. Also, Pellicori reported misophonia individuals may experience central auditory processing deficit since they are hyper focused and more concerned about the background noises such as chewing, drinking sounds unlike the individuals without CAPD who can easily tune out background noise and pay attention to signal [20]. This study aimed to check for any difference in binaural integration and binaural interaction between normal-hearing individuals with and without misophonia.

Methods

A cross-sectional study of university students with misophonia was carried out. All the participants in the study were informed about the procedure, and informed consent was taken. A total of 60 normal hearing subjects in the age range of 18-30 years participated in the study. Participants were divided into two groups: Experimental (n=30, 1 male and 29 females, age mean=22.03, SD=2.97 years) who had the diagnosis of misophonia and control (n=30, 12 males and 18 females, age mean=22.4; SD=2.28) who did not exhibit misophonia symptoms. Participants in both groups had normal hearing sensitivity, which was confirmed through pure tone audiometry, where all participants had pure tone averages (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) of less than 15 dB [21]. A calibrated audiometer was used for the same, and the procedure followed was a modified version of the Hughson-Westlake procedure [21]. Also, a calibrated tympanometer (GSI Tympstar V 2.0) confirmed normal middle ear functioning with a probe tone of 226 Hz. All the participants had either 'A' or 'As' type tympanogram and acoustic reflex was present within normal range at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz ipsilaterally and contralaterally. Participants with a history of otological complaints, noise exposure, ototoxic medications, tinnitus, hyperacusis, diabetes, or hypertension were excluded from the study. Hyperacusis was ruled out by measuring loudness discomfort level at frequencies between 250 Hz to 8000 Hz and for speech and it was found to be greater than 90 dB.

Schröder et al.'s diagnostic criteria for misophonia were used to confirm the misophonia diagnosis. The criteria include the presence or anticipation of specific sound that provokes an impulsive aversive physical reaction which starts with irritation or disgust that instantaneously becomes anger, the anger initiates a sense of loss of self-control with potential aggressive outbursts, and the individual tends to avoid the misophonic situation if not endures the situation with discomfort or anger, whether the anger, disgust cause significant distress and all these criteria should not be better explained by another disorder [2]. The Misophonia Assessment Questionnaire (MAQ) [22] was administered to assess the severity of misophonia. MAQ consists of 21 items evaluated from 0 to 3 points depending on how frequently the issue applies (0=not at all, 1=occasionally, 2=often, and 3=nearly always). Using the total score, misophonia severity is determined. Scores ranging from 0–11 were subclinical, 12–24 mild, 25–37 moderate, 38–50 severe, or 51–63 ex treme. A Google form link was shared with all the participants, through which each response was recorded. Only participants with definite misophonia diagnoses (mild and moderate) were considered in this study. The participant's characteristics in both groups are shown in Table 1.

DCV test material by Yathiraj (1999) was administered through a Windows media player with a calibrated supraural headphone [23]. The test is administered in a sound-treated room. The test stimuli include /pa/, /ta/, /ka/, /ba/, /da/, /ga/. It involves the presentation of different CV pairs with a time lag of 0 ms to both ears simultaneously. A free recall task was carried out in which the participants were required to attend and report both syllables presented. Right single score, left single score, and double correct scores were calculated for each participant. A schematic diagram for the following is shown in Figure 1.

Table 1. Demographic and basic audiological findings of the participants

	Individuals with misophonia	Individuals without misophonia
Mean age of participants	22.03±2.97 years	22.4±2.28 years
Number of participants	30	30
Number of ears	60	60
Tympanogram type	'A' type	'A' type
Mean pure tone average	9.81±2.42	10.03±2.21
Average ipsilateral reflex thresholds	87.63±0.86	89.18±0.73
Average contralateral reflex thresholds	98.42±0.81	99.07±091
Misophonia assessment questionnaire scores	Mild: 16.85±2.82 Moderate: 31.06±8.44	Nil

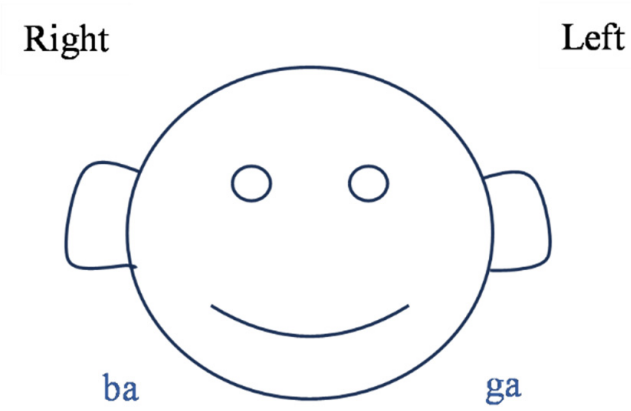

Figure 1. Schematic diagram for dichotic consonant-vowel test

MLD was administered through a calibrated audiometer in a sound-treated room. It was done at 500 Hz with a pulse mode of 2.5 Hz, and the presentation level was kept at 50 dB HL. Three conditions of MLD, SoNo, SπNo, and SoNπ, were tested. 'π' represents when source is out of phase and 'o' represents when the source is in phase. The participants were instructed to indicate when they heard the pulsed tone, and the thresholds were noted. A schematic diagram for the following is shown in Figure 2.

Statistical analyses

The IBM Statistical Package for Social Sciences (SPSS) version 25.0 (IBM SPSS Corp.; Armonk, NY, USA) was used to analyse the gathered data. The Shapiro-Wilk normality test was used to determine whether the data distribution was normal. To assess whether there were any significant differences between the control and experimental groups, inferential statistics were used. Independent t-tests were conducted on parametric data, and Mann-Whitney U-tests on non-parametric data.

Results

Comparison of binaural integration abilities between the two groups

Shapiro Wilk's test showed that DCV data were normally distributed. The results of the independent t-test showed $t(58)=0.77$, $p>0.05$ for double correct score, $t(58)=0.27$, $p>0.05$ for right single correct score, $t(58)=0.37$, $p>0.05$ for left single correct score. This indicated no statistically significant difference between misophonia and the control group for all three conditions. The mean and standard deviation for both groups are shown in Figure 3.

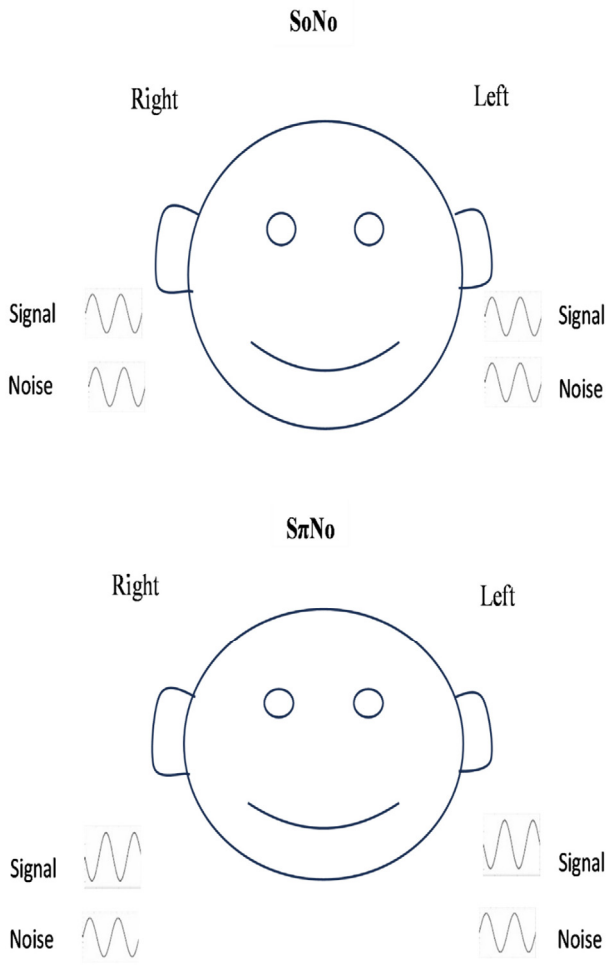

Figure 2. Schematic diagram for masking level difference test

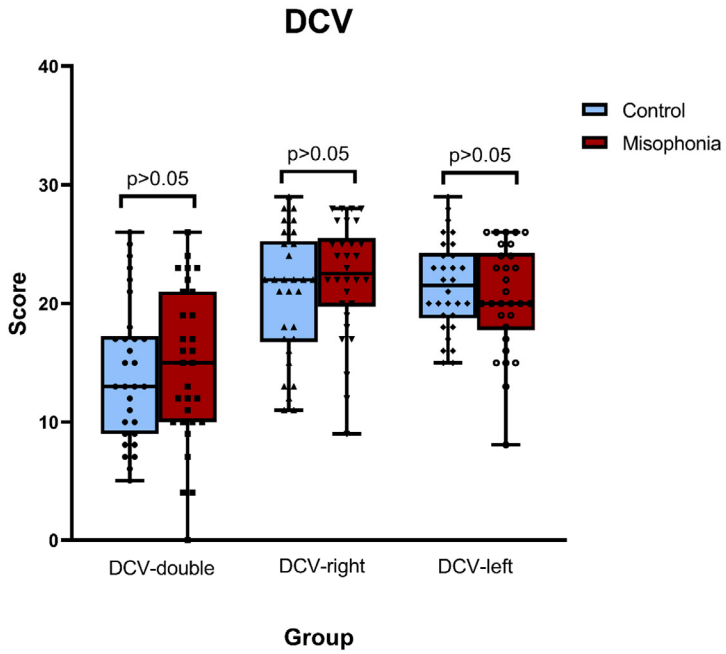

Figure 3. Mean and standard deviation of dichotic consonant-vowel test for control and misophonia group. DCV; dichotic consonant-vowel

Comparison of binaural interaction abilities between the two groups

Shapiro Wilk's test found that the data were not normal. Hence, a suitable non-parametric test was chosen. Mann Whitney U test was administered, and the results showed /Z/=1.08, p>0.05. This revealed no statistically significant difference between misophonia and the control group. The mean and standard deviation for both groups are shown in Figure 4.

For each group, right and left single correct scores were compared. Dependent t-test was administered and it showed that for the control group, t(29)=0.71, p>0.05 and for misophonia, it was found to be t(29)=0.9, p>0.05. This revealed no statistically significant difference between the ears in both groups.

Discussion

The study's outcome showed no significant differences in the MLD test and DCV test, which implies that binaural interaction and binaural integration are unaffected. This study considered only 30 misophonia participants with mild and moderate severity. Hence, this evidence demonstrates that individuals with these severities normally process binaural interaction and integration. Future research can include a larger pool of participants and a higher degree of misophonia severity. It is also essential to consider that the tests were conducted in an ideal situation optimum for listening in a quiet environment. These tests could be administered in adverse listening conditions, such as lower signal-to-noise ratios, in the presence of different types of noise, which would be more challenging to the participants.

Studies on misophonia have revealed no peripheral impairments [3, 24]. fMRI research showed hyperactivation of the right insula, right anterior cingulate cortex, right superior temporal cortex, and anterior insular cortex [7, 25]. Additionally, misophonia individuals have stronger mirroring neurons than the control group, and these neurons are more sensitive to trigger noises [26]. This evidence indicates abnormalities at the cortical level in misophonia, but the present study shows no abnormalities in binaural integration and interaction behaviorally.

Even though tinnitus and misophonia share a common pathophysiology, auditory processing is affected differently. In a study by Sanjay et al. it was found that interaural level difference, interaural time

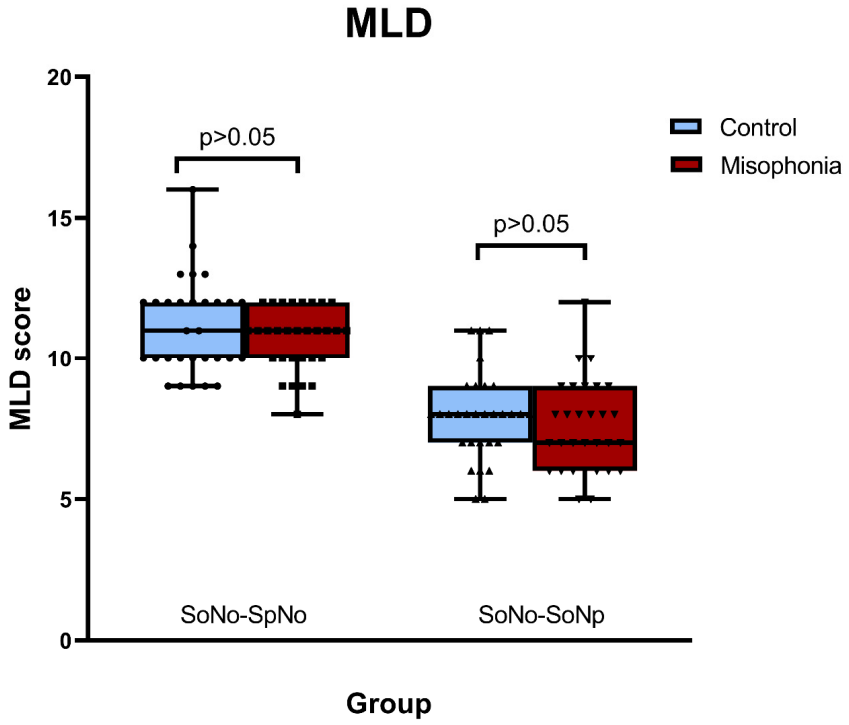

Figure 4. Mean and standard deviation of masking level difference for control and misophonia group. MLD; masking level difference

difference, and DCV test scores are poorer in the tinnitus group assessing binaural interaction and binaural integration [14]. In tinnitus individuals, habituation is affected compared to the control group, shown by N1-P2 amplitude being less pronounced [27]. Another research that studied binaural processing in tinnitus individuals through Auditory Brainstem Response (ABR) reported that in both monaural and binaural recording, wave I, III, and V had delayed latencies, and wave I and III amplitudes were reduced [16]. Also, when they compared Binaural Interaction Component)BIC(between both groups, they observed earlier BIC latency for wave I and V in the control group, whereas, with respect to amplitude, they did not find any significant differences. Another ABR study that evaluated tinnitus based on occasional and constant tinnitus demonstrated that constant tinnitus individuals had delayed wave V latency compared to occasional tinnitus individuals and the control group [28]. Joo et al. studied the effect of tinnitus duration on ABR and reported that individuals with subacute tinnitus duration (1–6 months) had reduced wave V amplitude and delayed wave V latency compared to individuals with acute tinnitus duration (<1 month) [29]. Also, they reported prolonged interpeak latency I-V during the subacute phase compared to the acute and chronic phases (>6 months). This indicated that after one month of symptoms, the compensatory reaction to tinnitus significantly reduced. Other ABR studies on tinnitus reported reduced amplitude of wave I and V, prolonged wave I, prolonged interpeak latency I-V, and increased interaural latency difference of wave V [30, 31]. A literature review of salicylate and noise-induced tinnitus on rat models showed reduced amplitude of wave I in both conditions whereas, increased amplitude of wave IV was observed in salicylate-induced tinnitus but not in noise-induced tinnitus [32]. The superior olivary complex is an essential structure in binaural processing and auditory brainstem responses, and all the abnormal findings in ABR can be attributed to the effect of binaural processing. Aryal and Prabhu reported no abnormal ABR findings in individuals with misophonia, supporting the findings obtained in the present study [33]. In most tinnitus complainers, tinnitus experienced is a continuous phenomenon, whereas misophonia gets triggered intermittently. This might be one of the reasons why binaural processing is affected differently in these groups. There are neurophysiological evidences such as reduced N1 amplitude in mismatch negativity, and significant differences in P1 and N1 latency which indicates differences in central auditory processing compared to the control group [18, 19] Also, according to Pellicori, those with misophonia may have a central auditory processing deficit because they are more focused and aware of the background noises compared to individuals without CAPD who can easily filter out background noises [20]. The tests used in this study were simple and the severe misophonia group was not considered. Hence, more complicated tests and on severe misophonia can shed more light on this condition. Since binaural integration and interaction findings are different in individuals with tinnitus and misophonia, we can hypothesize that there could be some difference in the mechanism of binaural processing between these groups.

Conclusion

The present study is the first to study binaural interaction and integration in misophonia individuals. The above-mentioned processes were investigated using masking level difference and dichotic consonant vowel, respectively. The results showed that there are no significant differences between individuals with and without misophonia. A few limitations of the study were the number of participants considered and the misophonia severity assessed, which was only to a moderate degree. Also, entire central auditory processing tests were not administered in this study, more studies on other central auditory processes are essential. Hence, further research on misophonia tackling these limitations could be undertaken.

Ethical Considerations

Compliance with ethical guidelines

The study obtained ethical committee approval from the institution ethical review board with approval reference SH/ERB/RP/2022/32. All the participants provided informed consent to participate in the study.

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Authors' contributions

HVM: Study design, acquisition of data, and drafting the manuscript; KVN: Study design, supervision and critical revision of manuscript; PP: Study design, supervision, statistical analysis, interpretation of the results and critical revision of the manuscript.

Conflict of interest

There is no conflict of interest to disclose.

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