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Sensitivity to noise cancellation, also known as "eardrum suck"

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ABSTRACT

There are a significant number of people who experience an adverse sensitivity to active noise cancellation technology, also known as "eardrum suck." "Eardrum suck" describes the most common symptom—a feeling of "pressure" in the ear, as if in an ascending or descending airplane. Despite being reported by many noise-cancelling users in product reviews and media, there is little found on this phenomenon in the scientific community. In this paper, we provide an initial assessment of the prevalence of this sensitivity, look at the onset time of the symptoms, note any associations with form factor, explore the range of symptoms felt beyond aural fullness noting their similarities to disorders of the middle ear, discuss common methods of relief and exacerbation, and consider conditions for designing an effective psychoacoustic test.

1 Introduction

Sensitivity to active noise cancellation (ANC) technology affects many headphone and earbud users. Coined by *The New York Times*, "eardrum suck" describes the most common symptom, a feeling of *aural fullness*, or sensation of pressure or blockage in the ear [1]. The sensitivity may also be accompanied by headaches and nausea. For some, the feeling goes away or can be adapted to. However for others, symptoms may worsen, becoming uncomfortable, disorienting, and even painful to the point where they cannot wear the device anymore.

In this paper, we provide an initial assessment of the prevalence of eardrum suck; survey features of the

symptoms, including onset time, form factor associations, and range, highlighting their similarities to middle ear disorders; discuss common methods of relief and exacerbation; and consider design conditions for an effective psychoacoustic test. These insights are based on a set of mostly small-scale subjective studies conducted in the United States.

Assessments of the prevalence of eardrum suck thus far have been anecdotal or conducted on a small scale. Many users have reported feeling the symptoms immediately, but some users report lingering symptoms even after they've taken the device off. Users with this experience tend to have more severe symptoms. It is also unknown if the sensitivity is tied to a specific form

factor, like the headphone, earbud, or open-fit form factor.

Prior to this paper, the main symptoms reported were aural fullness, headaches, dizziness, and nausea [1]. These symptoms share many similarities to disorders of the middle ear [2], and understanding these mechanisms may illuminate any physical processes that may be occurring with ANC sensitivity symptoms.

The main symptom, aural fullness, is commonly caused by a difference in air pressure between two cavities in the ear, the external auditory canal (EAC) and the middle ear [3] (see Fig. 1). This difference in pressure causes the eardrum (tympanic membrane) separating the two cavities to displace either inwards or outwards from its relaxed position [4]. Opening of the Eustachian tube is the main mechanism by which the middle ear can equalize to match the EAC pressure by letting air in and out of the middle ear. The left and right Eustachian tubes both connect to a common cavity, the nasopharynx [5].

A difference in pressure between the EAC and middle ear can also be caused by displacement of the eardrum due to engagement of the tensor tympani reflex or stapedius reflex [6], reduction of pressure in the middle ear due to transmucosal gas exchange between the middle ear air and the middle ear lining (middle ear mucosa) [7], and/or exacerbated by dysfunction of the Eustachian tube, resulting in a worsened or even failed mechanism for equalizing the middle ear pressure (Eustachian tube dysfunction) [5]. Middle ear disorders are also associated with balance problems [2], another symptom of ANC sensitivity.

In addition to understanding the range of symptoms experienced, we investigate the effect of various common conditions on ANC sensitivity. These conditions are ranked and discussed as possible methods of relief and exacerbation. Conditions include playing music or noise, being in a noisy versus quiet environment, turning ANC off, and going into transparency mode.

The most effective methods of relief and exacerbation are then used as conditions for designing an effective psychoacoustic test.

2 Methods

2.1 Prevalence

A study exploring earbud usage patterns and behaviors was conducted on 977 users of premium ANC earbuds

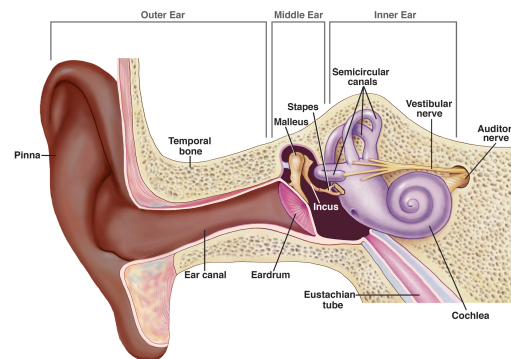


Fig. 1: Diagram of ear [8].

(59% male, 41% female, 2 non-binary/third gender) who "regularly use their ANC device." Participants were asked to select the comfort problems that they typically experience with their wireless earbuds, one of which included "eardrum suck." "Eardrum suck" was defined as "a phenomenon in which constant pressure is applied to the ear, similar to being in a vacuum or feeling like your ears need to be popped."

2.2 Symptoms

Several small-scale subjective studies were conducted to gauge onset time, form factor associations, and range of symptoms.

Onset time of ANC-related symptoms was collected from a survey sent to 45 people with self-reported "eardrum suck." In the survey, participants were asked to select the onset time of their symptoms from three options: 1) "Immediately," 2) "After a few minutes," and 3) "After an hour or more."

Participants in the survey were also asked to select or write in an ANC device that has the worst "eardrum suck." The list of pre-defined devices included products of two form factors, headphones and earbuds.

Additionally, 11 participants from the survey (male=7, female=4) with symptoms ranging from moderate to severe were brought in and asked to wear "open-fit" ANC earbuds to see if the sensitivity was present with an open-ear form factor.

To explore the range of symptoms caused by ANC sensitivity, a survey was conducted on six participants with

self-reported sensitivity and with unique symptoms ranging from moderate to severe (male=3, female=3). Participants were given a list of symptoms along with an explanation of each symptom, and asked to wear ANC earbuds while identifying which symptoms on the list were present. Additionally, participants were allowed to add any sensations that were not on the list, and those symptoms were added for future participants. If the participant identified presence of a headache, they were asked to specify its location.

The list of symptoms was gathered from Westcott et al. [11] on Tonic Tensor Tympani Syndrome (TTTS). TTTS is a cluster of symptoms caused by over-activity of the tensor tympani reflex, one of two middle ear muscle reflexes. The tensor tympani reflex is an anticipatory reflex which pulls the eardrum inwards to protect the ear from hearing loss [6]. The TTTS symptom list was chosen as it is the most comprehensive and most similar to symptoms reported by users with ANC sensitivity. Other middle ear disorders considered included ear barotrauma, Eustachian tube dysfunction, alternobaric vertigo, and disorders of the middle ear muscle reflex [9] [5] [10].

Symptoms were divided into four categories: physical sensation in ear, hearing change, disorientation, and physical sensation outside of ear. They are as follows:

Physical sensation in ear:

- Aural fullness or pressure, "blockage"
- Sharp pain in the ear
- Dull ache in the ear
- Tympanic flutter

Hearing change:

- "Muffled" hearing (quieter)
- Hyperacusis (louder)
- Diplacusis, "double-hearing" (echoes, off in timing)
- Distorted hearing

Disorientation:

- "Disordered" balance/mild vertigo (often described as 'sway' - like being on a boat)
- Headache
- Nausea

Physical sensation outside of ear:

- Numbness around the ear

- Burning sensation around the ear
- Pain in the cheek
- Pain in the TMJ (throat, mouth, jaw)
- Numbness/burning/pain along the side of the neck¹
- Heaviness in chest¹
- Numbness in arms¹

2.3 Common methods of relief and exacerbation

Common methods of relief and exacerbation were explored. Six participants with self-reported sensitivity to ANC ranging from moderate to severe were asked to rate the overall feeling of eardrum suck under various common conditions. The study was conducted in an office with ambient office noise, and the rating scale used was from 0 (no feeling) to 4 (very uncomfortable), in increments of 0.1.

Participants were asked to wear the ANC earbuds and rate the overall feeling of their symptoms for each ear. This rating was used as the reference condition. They were then asked to rate the feeling of "eardrum suck" in various new conditions: transparency mode, ANC off mode, with room noise playing, with three types of sounds playing to the earbuds, and with asymmetric ANC (ANC off in one ear, ANC on in the other ear, two conditions total, one for each side). The room noise was pink noise played with a speaker at around 65 dB-SPL. The three sounds used were music, low-frequency noise, and high-frequency noise that all lasted several seconds. Participants had the ability to toggle between the reference condition and the new condition. The effect of the condition on ANC sensitivity was calculated by taking the difference between the rating of the new condition and the reference condition.

3 Results

3.1 Prevalence

Of the 977 people surveyed, 117 users ($12 \pm 3\%$) of users reported that they experienced eardrum suck. For users of the top three major premium noise-cancelling earbud brands, the results were similar, ranging from 12% to 14%.

¹Added by participant.

3.2 Symptoms

The onset time of the symptoms was immediate for most people ($n=26$). A significant number of people experienced a slightly longer onset time of a few minutes ($n=13$), and even a few hours ($n=6$). Qualitatively, some reported that the symptoms faded over time, while others reported that the symptoms worsened over time and even persisted after they took the device off. The symptoms that persisted over time were often headaches and nausea.

Of the 45 survey entries, the ANC device with the worst form factor was split evenly between headphones ($n=23$) and earbuds ($n=22$). Of the 11 participants that additionally tried the open-fit ANC earbuds, all 11 participants reported feeling ANC sensitivity symptoms with the open-fit ANC earbuds. Qualitatively, users had a more asymmetric fit when wearing the open-fit ANC earbuds.

The range of symptoms experienced are shown in Table 1. The location of the headache was reported as "forehead," "front side," "between the eyes," and "forehead and also in the back of my head." Headache locations are consistent with a tension headache [2]. Of the four categories of symptoms, every participant experienced physical sensation in the ear and disorientation symptoms. Symptoms in the less-common categories ("change in hearing" and "physical sensation outside of ear") were present in participants with the most severe sensitivity.

3.3 Common methods of relief and exacerbation

The average effect of common methods on ANC sensitivity are shown in Table 2, and individual results are shown in Tables 3, 4, 5, and 6 in the Appendix. Transparency mode was the greatest reliever of ANC symptoms. Playing music and noise either improved symptoms or had no effect. Participants were sensitive to different audio content. Turning ANC off also relieved symptoms, although they were worsened for one participant.

Asymmetric ANC had mixed results. For some, it relieved their symptoms, while for others, it worsened them. In some cases, whether or not the symptoms improved or worsened depended on which ear the noise cancellation was on. Furthermore, some participants reported still feeling pressure in the ear that had no noise cancellation.

Table 1: Symptoms reported by six participants.

Symptoms	Count
Physical sensation in ear	6/6
Aural fullness	6/6
Sharp pain in ear	2/6
Dull ache in ear	1/6
Tympanic flutter	0/6
Change in hearing	3/6
"Muffled" hearing (quieter)	2/6
Hyperacusis (louder)	1/6
Diplacusis (double-hearing)	1/6
Distorted hearing	0/6
Disorientation	6/6
"Disordered" balance	5/6
Headache	4/6
Nausea	2/6
Physical sensation outside of ear	1/6
Pain in TMJ	1/6
Numbness/burning/pain along side of neck ¹	1/6
Heaviness in chest ¹	1/6
Numbness in arms ¹	1/6
Numbness around ear	0/6
Burning sensation around ear	0/6
Pain in cheek	0/6

4 Discussion

Overall, the observations made in this paper are mostly from subjective studies using a small sample size and are in no way conclusive or representative of the population. However, they can show what trends may be present.

4.1 Prevalence

The actual percentage of the population that experiences sensitivity to ANC is likely higher than 12% as people with severe sensitivity are less likely to have or use premium ANC products *regularly*, and thus would not be included in this study. The 12% result can thus be considered the *minimum* percentage of people in the population who experience ANC sensitivity. Additionally, ANC sensitivity does not seem to be associated with a particular brand.

Table 2: Change in overall feeling of "eardrum suck" due to common conditions (n=6). A negative change is "relieving" and a positive is "worsening."

Condition	Avg.
Transparency	-0.75
ANC off	-0.45
Play music	-0.37
Play LF noise	-0.33
Play HF noise	-0.27
Left ear ANC (left ear)	-0.15
Right ear ANC (right ear)	-0.12
Left ear ANC (right ear)	-0.08
Right ear ANC (left ear)	+0.05
Room noise	+0.08

4.2 Symptoms

For most, the feeling of ANC sensitivity is immediate, though the onset time may depend on the symptoms. It is possible that the main symptom, aural fullness, has a more immediate onset/offset time, while other symptoms may have a slower onset/offset time. Participants have reported that headaches and nausea may have a slower onset time, but may also linger for longer, even after the device has been removed. This should be studied further.

ANC sensitivity seems to be present and common on both headphone and earbud form factors, with no clear distinction. With the arrival of more ANC open-fit products, it can be expected that ANC sensitivity will still be present on this new form factor, though the degree is still not understood. Future work could be done to explore how fit variation affects ANC sensitivity, as more fit variation is expected from the open-fit form factor.

From surveying only six participants, symptoms of ANC sensitivity spanned well beyond the commonly known symptoms of aural fullness, headache, dizziness, and nausea, including changes in hearing and physical sensations outside of the ear. This adds to the list of growing similarities between ANC sensitivity and disorders of the middle ear.

4.3 Common methods of relief and exacerbation

Transparency mode was a better reliever than turning ANC off. This is likely due to transparency mode being more similar to natural hearing with no device on. Although turning the ANC off does provide relief, it still includes passive cancellation from the physical blocking of sound from the device itself.

Music and noise either improved or had no effect on ANC symptoms, making it a consistent method of relief. Participants were sensitive to different audio content implying that the frequency range of relief may be different for each person.

Room noise does not show a strong trend of relief or exacerbation. However, participants have commented that the symptoms are more pronounced in the presence of room noise when *switching* between transparency and ANC mode than in a quiet room. The difference in the transition between ANC states may have a significant impact on ANC symptoms and should be studied further.

It is of note that participants who experienced worsening symptoms from asymmetric ANC still had pressure in the ear with no ANC, hinting that the symptoms may be linked between ears. Further studies could be done to see if ANC sensitivity is a bilateral effect.

4.4 Psychoacoustic testing

Based on the results of these surveys, we recommend the following guidelines for future psychoacoustic tests comparing noise cancellation conditions. Tests should be kept as short as possible to reduce the amount of discomfort the participant feels. Because symptoms may worsen or improve over time, participants should be able to complete each question quickly and be given a maximum of two or three options to compare per question. The participant should have the ability to switch to transparency mode at any time throughout the test to provide relief from their symptoms. If comparing various noise cancellation levels, background noise should be played throughout the test to increase the contrast in between noise cancellation levels and to possibly increase the presence of the ANC sensitivity.

5 Summary

As ANC technology becomes more ubiquitous, adverse sensitivity to noise cancellation may become more common. In this paper, we provide an initial assessment of the prevalence of eardrum suck; survey the symptoms' onset time, association with form factor, and range of symptoms, noting their similarities to disorders of the middle ear; discuss common methods of relief and exacerbation; and consider conditions for designing an effective psychoacoustic test. These insights are based on a set of mostly small-scale subjective studies conducted in the United States.

A minimum of 12% of the population experiences ANC sensitivity. The onset time of the main symptoms are immediate, but some symptoms may have a slower onset time and may linger after the device is taken off. ANC sensitivity is present on all form factors, even the open-fit form factor, and there is no strong trend towards a particular form factor. The range of symptoms experienced spans well beyond aural fullness, sharing many symptoms with disorders of the middle ear.

One of the best relievers of ANC sensitivity is transparency mode, which may be a slightly better reliever than turning the ANC off due to the presence of passive cancellation when ANC is off. Playing music or noise to the driver also provides relief for some, though the type of audio content that is effective may be unique to each person. Being in a louder environment has a mixed effect on ANC sensitivity, and it may be that the difference between ANC states has a bigger effect. For some, asymmetry may also exacerbate the sensitivity. Users who experience a worsening of symptoms with asymmetric ANC may also experience aural fullness in the contralateral ear (ear with no ANC), suggesting a possible linking of symptoms between ears.

When designing a psychoacoustic test to compare ANC conditions, it is recommended to keep test as short as possible to minimize the participant's discomfort. Because symptoms may change over time, it is recommended that each question should be as short and simple as possible, limiting to two to three options per question. The participant should have the ability to switch to transparency mode at any time to provide relief from their symptoms. Background noise may be played throughout the test to increase the contrast between conditions.

Though it has been suggested that ANC sensitivity may be an imagined phenomenon with no actual physical change happening in the ear, it is possible that there could be physical effects happening within the middle ear that cause the ANC symptoms, and this should be explored more. Finally, subjective tests were mostly conducted with a small sample size and are meant to point to possible trends rather than to be conclusive. Future work should be done across a wider and more diverse population.

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7 Appendix

Table 3: Common methods of relief and exacerbation: transparency, ANC off, and room noise

Condition	S1	S2	S3	S4	S5	S6
Transparency	-1.0	-0.5	-1.0	-1.0	-1.0	0.0
ANC off	-0.5	0.0	-1.0	-0.7	+0.5	-1.0
Room noise	0.0	-0.5	-0.5	+1.0	+0.5	0.0

Table 4: Common methods of relief and exacerbation: play music and noise to earbuds

Condition	S1	S2	S3	S4	S5	S6
Music	-0.2	-0.5	0.0	-1.0	-0.5	0.0
LF noise	0.0	0.0	-0.5	0.0	-1.0	-0.5
HF noise	-0.2	+0.1	0.0	-0.5	-1.0	0.0

References

- [1] Butterworth, B. and Dragan, L., "Do Noise-Cancelling Headphones Hurt Your Ears? You're Not Alone." *The New York Times – Wirecutter*, 2019, online; [Accessed 09-07-2025].
- [2] Klockhoff, I., "Impedance Fluctuation and a "Tensor Tympani Syndrom"," in *Proceedings of the 4th International Symposium on Acoustic Measurements*, pp. 69–76, Lisbon, 1979.

Table 5: Common methods of relief and exacerbation: ANC in left ear

Subject	Left	Right
S1	+0.3	+0.5
S2	-0.5	-0.5
S3	0.0	+0.5
S4	-0.2	-1.0
S5	+0.5	+1.0
S6	-1.0	-1.0

Table 6: Common methods of relief and exacerbation: ANC in right ear

Subject	Left	Right
S1	-0.2	0.0
S2	0.0	-0.5
S3	+0.5	0.0
S4	-1.0	-0.2
S5	+1.0	0.0
S6	0.0	0.0

- [3] Park, M. S., Lee, H. Y., Kang, H. M., Ryu, E. W., Lee, S. K., and Yeo, S. G., "Clinical Manifestations of Aural Fullness," *Yonsei Medical Journal*, 53(5), pp. 985–991, 2012, doi: 10.3349/ymj.2012.53.5.985.
- [4] Voss, S. E., Rosowski, J. J., Merchant, S. N., and Peake, W. T., "Acoustic responses of the human middle ear," *Hearing Research*, 150(1), pp. 43–69, 2000, ISSN 0378-5955, doi:https://doi.org/10.1016/S0378-5955(00)00177-5.
- [5] Hamrang-Yousefi, S., Ng, J., and Andaloro, C., "Eustachian Tube Dysfunction," in *StatPearls*, StatPearls Publishing, Treasure Island (FL), 2023.
- [6] Fournier, P., Paleressompoulle, D., Esteve Fraysse, M.-J., Paolino, F., Devèze, A., Venail, F., and Noreña, A., "Exploring the middle ear function in patients with a cluster of symptoms including tinnitus, hyperacusis, ear fullness and/or pain," *Hearing Research*, 422, p. 108519, 2022, ISSN 0378-5955, doi:https://doi.org/10.1016/j.heares.2022.108519.
- [7] Hamada, Y., Utahashi, H., and Aoki, K., "Physiological gas exchange in the middle ear cavity," *International Journal of Pediatric Otorhinolaryngology*, 64(1), pp. 41–49, 2002, ISSN 0165-5876, doi:https://doi.org/10.1016/S0165-5876(02)00040-X.
- [8] NIH/NIDOC, "Parts of the Ear," <https://www.nidcd.nih.gov/sites/default/files/2022-03/nidcd-ear-illustration-2000x1479.jpg>, 2022, [Accessed 15-07-2025].
- [9] O'Neill, O. J., Brett, K., and Frank, A. J., "Ear Barotrauma," in *StatPearls*, StatPearls Publishing, Treasure Island (FL), 2025.
- [10] Francescon, D., Jamal, Z., and Cooper, J. S., "Alt ernobaric Vertigo," in *StatPearls*, StatPearls Publishing, Treasure Island (FL), 2023.
- [11] Westcott, M., Sanchez, T. G., Diges, I., , Saba, C., Dineen, R., McNeill, C., Chiam, A., OKeefe, M., and Sharples, T., "Tonic tensor tympani syndrome in tinnitus and hyperacusis patients: A multi-clinic prevalence study," *Noise and Health*, 15(63), pp. 117–128, 2013, ISSN 1463-1741, doi: 10.4103/1463-1741.110295.