International Journal of Speech and Audiology

E-ISSN: 2710-3854
P-ISSN: 2710-3846
IJSA 2023; 4(2): 19-22

www.rehabilitationjournals.com
Received: 23-05-2023
Accepted: 03-07-2023

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A literature review on noise cancellation techniques in audiometry testing

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Abstract
This paper identifies current research on noise canceling methods applied to hearing screening tests. Investigations are also being conducted on audiometry issues and solutions related to real-time noise reduction techniques. Background noise levels at testing locations are reduced down below the threshold specified by the American National Standards Institute (ANSI) using sound proof studios. The test must be performed in an environment where ambient noise levels are less than the maximum permitted noise levels to avoid false positive screening findings. Excessive ambient noise is a major problem for hearing screening since it masks pure tone stimuli, particularly at frequencies below 500 Hz. As a result, false findings are produced. Ambient noise might make it difficult for those with hearing loss to understand what is being said. In audio-metric testing, noise reduction strategies have been addressed in a variety of ways over the years. This is a survey of journals in the field of noise canceling techniques in hearing screening, with the most recent articles highlighted.

Keywords: Hearing screening, ambient noise, audiometry, active noise control, headphone audiometry

1. Introduction
The viability of various noise reduction approaches in relation to various headphone types and the issues that cropped up during the test are reported in this paper. Supraaural, insert, and circumaural earphones are the three types of earphones used in screening tests. Supra-aural earphones have various disadvantages in this regard, such as poor interaural attenuation, poor ambient-noise attenuation, and a significant occlusion effect. The occlusion effect happens when anything covers the outer portion of an ear canal, causing the person to hear echo. It is caused by sound energy created internally that resonates in the cavity between the eardrum and the hearing aid. Because of the seal produced in the ear canal, insert earphones are more extensively utilized than supra-aural earphones for ambient noise attenuation. Interaural attenuation is also better than with supra-aural earphones. For many years, circumaural earphones have been the most extensively utilized variety in hearing screening. The Koss HV/1A circumaural earphone was the first to be recognised by the American audiometer standard. Circumaural earphones have a lower occlusion effect and better ambient noise suppression than other types of headphones. As a result, circumaural earphones are commonly employed in screening audiometry, which is often undertaken in nonclinical settings when noise levels are too high for reliable hearing threshold testing using supra-aural earphones. Hearing screening has been found to have a unique limitation due to low-frequency background noise [5]. Ambient noise at low frequencies is common in industrial and institutional settings. Even when insert earphones and portable single walled sound booths are utilized, low frequency noise is present. Due to high low-frequency ambient noise, the evaluated mobile facilities frequently failed around 125, 250, and 500 Hz [1]. Outside of a sound booth, there is a need to enhance the technique for conducting hearing screening tests. Table 1 provides the ANSI S3.1-1991 Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms. All people who test their hearing, as well as audiometric test room distributors, installers, designers, and manufacturers, should utilize this Standard.

Table 1: Maximum permissible ambient noise levels for audiometric testing

Frequency	Supra-aural Headphones	Insert earphones
500 Hz	21	50
1000 Hz	26	47
2000 Hz	34	49
4000 Hz	37	50

To give clinical measures stability and reliability, standards are developed and amended. They should be legible, practical, and beneficial, as well as based on the most up-to-date research. Hopefully, the working group was successful in achieving these objectives when drafting ANSI S3.1-1991 [9].

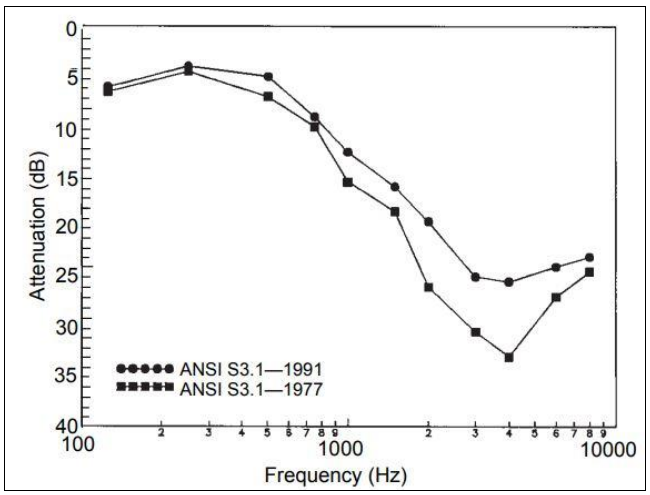

Fig 1: Comparison of Earphone attenuation values used in ANSI S3.1- 1991 and in ANSI S3.1-1977 [9]

2. Material and Methods

The study examined the possibilities of active techniques to minimize low frequency noise below 500 or 1000 Hz because of the limitations of passive techniques. A DSP controller, microphones, and loudspeakers are used in the active noise control (ANC) system, which consists of a feed forward and feedback system. In this review, recent research from the last five years is analyzed.

2.1 Active Noise Reduction (ANR) Headsets

The creation of out-of-phase sound waves to attenuate incoming background noise is part of Active Noise Reduction, which works on the idea of phase cancellation. The concept is to record background noise, invert it to create ”anti-noise,” and then mix it in with the output signal, which contains original music. At the point where it reaches our ears, the anti-noise signal cancels out the actual background noise. With technological advancements, active noise control (ANC) may now be applied to headphones, potentially reducing the issues caused by low-frequency noise [2]. ANR headphones function well at frequencies below 1500 Hz due to the characteristics of sound waves. ANR headphones, like circum-aural headphones, reduce sound in a passive manner. The Bose Quiet Comfort 15 are circumaural earphones that are designed to eliminate unwanted noise by passively filtering it through the earpiece [3].

2.2 Utilization of Insert earphones

During audiometry testing, insert earphones are utilized to overcome theoretical and clinical restrictions. They offer a number of potential benefits, including lowering the noise on the audiometry threshold [8]. The insert earphones achieved the maximum attenuation in the high frequencies, which was around 28 dB at 1,000 Hz. The combination of inserts with ANC headphones, on the other hand, significantly enhanced attenuation at all frequencies. The HD 280 pro headset is generally utilized by musicians and audio engineers as a consumer product. It reduces ambient noise better and has a lower occlusion impact than the HDA 300, although it falls short of the HDA 200 in both categories [5].

2.3 Combination of Insert and ANC earphones together

Patients were given ANR headphones to wear on top of insert earphones. The fit of the earmuffs was carefully considered. When ANR headphones were used, they were tested in both active and passive states. Audiograms were then conducted with 30 or 40 dB of matched narrow band noise while the ANR headphones were active. The headphones were then removed and a standard audiogram was conducted within 30- and 40-dB sound fields without the use of ANR audiometry. A third “standard” audiogram was then conducted with no ANR headphones or background noise. The attenuation of inserts and ANR headphones at 1000 Hz was 45dB [1].

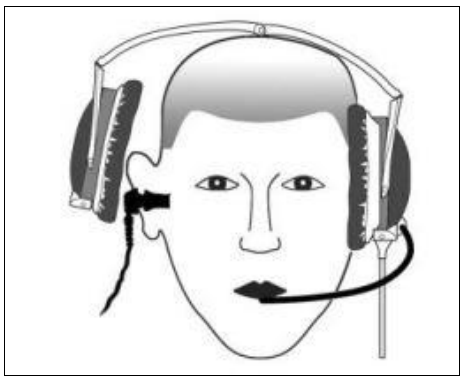

Fig 2: Setup for Insert and ANR headphones together [1]

2.4 Filtered-x least mean square (FxLMS) algorithm

For active noise control (ANC) systems, the filtered-x least mean square (FXLMS) method is frequently used. However, the FXLMS algorithm results in a compromise between noise reduction performance and convergence time because a fixed step-size is used [14, 15]. The main drawback of the FXLMS algorithm is the use of fixed step-size, which results in a compromise between noise reduction performance and convergence speed of the ANC systems.

3. Results

Examining the performance of three audiometry-suitable earbuds (Sennheiser HDA 200, HDA 280 Pro and HDA 300) earphones has been utilized in audiometry. American and international audiometer standards offer reference equivalent threshold sound pressure levels (RETSPLs) for the earphone (ANSI S3.6-2010 and ISO 389-8-2004). The HD 280 PRO can provide up to 32 dB of passive noise attenuation. Fig 4 represents the passive noise attenuation capability of various sennheiser headphones used in audiometric screening. Sennheiser has developed a new earphone, the HDA 300, as a replacement for the HDA 200. The HD 280 Pro is a consumer product that could be a low-cost replacement for the HDA 300. We examined input impedances, sensitivities, ambient noise attenuation, occlusion impact, and total harmonic distortion in addition to determining RETSPLs (THD). The HD 280 Pro earphones have poorer noise isolation than the HDA 200 and DD450 earbuds. This is due to the earphone enclosures characteristics. Hearing protection is provided by the HDA

200 and DD450 earphones, which are housed in an enclosure. The HD 280 Pro is housed in a budget-friendly circumaural casing [5].

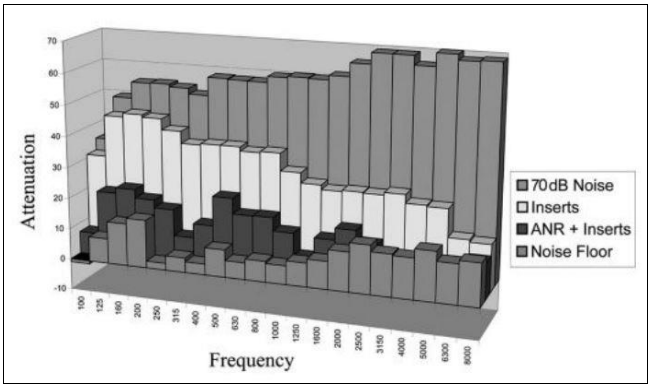

Fig 3: Attenuation capability of different methods [1]

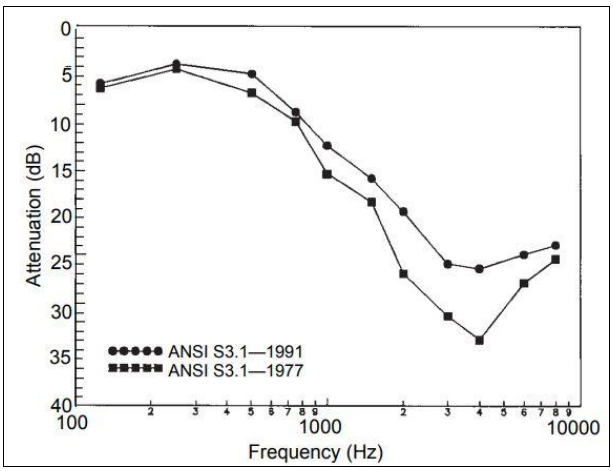

Fig 4: Passive Ambient Noise attenuation (HDA 280 Pro, HDA 200 and HDA 300 [1]

4. Discussion

ANR audiometry provides a much more portable and effective solution for screening audiometry. Even when inserts are used in combination with a single-walled sound booth, ANSI standards are often not met in some mobile test facilities. ANR audiometry could add another level of attenuation to improve test reliability. The cost reductions of ANR audiometry in terms of infrastructure could be a significant element in the design of future testing facilities. NC headphones have a better noise reduction capacity than TDH-39 earphones across nearly all frequencies. Because noise is evaluated on a logarithmic scale, NC headphones have a 6 dB and 2 dB stronger noise attenuation at 250 Hz and 500 Hz, respectively, than TDH-39 earphones, implying that listeners will feel less low frequency noise when NC headphones are worn. Noise attenuation below 500 Hz should result in fewer masking effects on a test tone at 500 Hz. Non-adaptive feedback ANC, which is prevalent in commercial NC headphones, can reduce noise by up to 20 decibels for frequencies below 700 Hz. The level of attenuation provided by the various methods of ear protection was calculated by subtracting the sound level measured at each specific frequency. These results [1] are displayed in Fig.3. The HATS [Head and Torso Simulator 4128C] unit and monitoring equipment were used in this experiment, which produced a weighted curve by delivering 70 dB SPL pink noise into the chamber. The reduction in noise caused by the use of ANR headphones was not entirely due to the ANR technology. The muffs helped to attenuate the sound. Passive attenuation is only effective at mid to higher frequencies, just like the insert earphones.

5. Conclusions

The findings of this study show that the ANR headphones are a significantly more portable and effective solution for audiometry screening. ANSI criteria are frequently not reached in some test facilities, even when inserts are utilized in conjunction with a single walled sound proof room. ANR audiometry adds an additional level of attenuation to the screening process, and it doesn't require the use of a sound booth. Insert earphones were used to circumvent clinical constraints during screening, although they were only effective at high frequencies.

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