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Short Communication

Earplug-Type Earphone with Built-in Microphone Improves Monosyllable Intelligibility in Noisy Environments

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Headsets (earphones or headphones equipped with a microphone) are widely used at work sites such as call centers or manufacturing facilities. Among workers using these headsets in noisy environments, adverse health effects may result not just from exposure to environmental noise, but to loud voice signals from the apparatus itself[1–3]. A device composed of a bone-conduction microphone and a speaker-equipped earmuff has been developed. Although the device effectively reduces the noise-induced temporary threshold shift, its weight makes it impractical for real-world use[3].

We undertook an extensive search of breakthrough technologies in the areas of hearing protectors, microphones, speakers, and headsets, including earphones developed for portable audio-players, then incorporated a newly available earplug-type earphone with built-in microphone (EM) as a telecommunication device for workers required to engage in communications tasks at noisy work sites.

The effectiveness of the EM was evaluated as a dual-function device providing both communication functions and hearing protection in noisy work environments.

Materials and Methods

We used an EM (inCore, NAP Enterprise Co., Ltd.) incorporating a minute microphone-loudspeaker capsule inserted into the external ear canal and shielded from the exterior environment by a five-layer silicon rubber ear pad. These ear pads are available in three sizes: small, medium, and large (10.6, 12.5, and 14.6 mm diameter).

Real Ear Attenuation at Threshold test

A total of 20 university students were recruited for this study. All subjects were confirmed to have pure-tone air-conduction hearing threshold levels ≤15 dB at all the octave-band center frequencies from 125 Hz to 8 kHz, using an audiometer (AA-79, RION). Subjects were ranged in age from 18–27 yr (average age of 20.9 yr), and half of them were male. The ear canals and eardrums of each subject were carefully inspected and the diameter of the ear canals was measured with an E.A.R./Aearo EARGAGE earplug-sizing device.

Four loudspeakers were placed inside a circle with a diameter of 1.55 m in an anechoic chamber. Subjects were asked to sit at the center of this circle and to face in a direction defined as azimuth 0°. Loudspeakers 1 through 4, respectively, were placed at points of 45°, 135°, 225°, and 315° azimuth.

The attenuation of EM was determined using the Real-Ear Attenuation at Threshold test (REAT test). REAT test determined the difference between the minimum level of sound that each subject could hear without wearing an earplug and the level needed when the earplug was worn[4]. Subjects were allowed to choose a pair of ear pads after trying all sizes in a broadband noise field of 65 dBA under the supervision of an examiner.

Determinations of hearing level were made using test signals consisting of white noise, filtered into one-third octave bands ranging from 125 Hz to 8 kHz. The signals were pulsed at regular intervals for 500 ms, followed by 500 ms of silence. Signals were presented through four loudspeakers (111AD, BOSE) controlled by a computerized sound attenuation measurement system[5]. The levels of frequency characteristics ranged from 40.0–52.6 dB (125 Hz–8 kHz) by one-third octave analysis with an acoustic analyzer (type 7700, Brüel & Kjær) in a pink noise field of 60 dB.

If a subject responded to the signal at a certain noise level (dB), the next signal was presented at 7.5 dB lower. If the subject failed to respond to a signal, the next signal was presented at 2.5 dB higher. Three consecutive positive responses were required to identify audible levels. We performed two series of measurements with and without EM. The order was counterbalanced across subjects to eliminate order effect. A half of each gender was first measured with EM and the rest started without EM. Arithmetic mean attenuation and standard deviation were used to determine the noise reduction rating (NRR) standardized in the U.S. (EPA, 1979)[6].

Speech audiometry

We compared the results of speech intelligibility with EM to those with supra aural headsets; applying the same measurement protocol. Among the above subjects, 10

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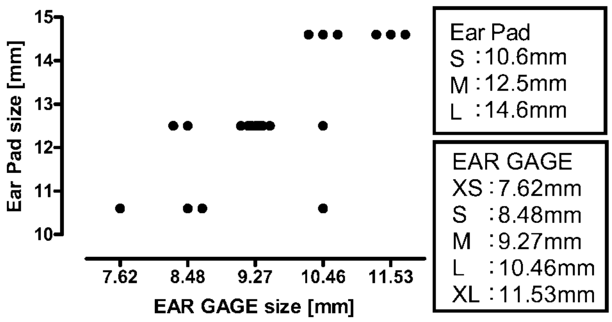

Fig. 1. Ear pad selection with respect to size of external ear canal measured by EAR-GAGE in Real Ear Attenuation at Threshold test (n=20).

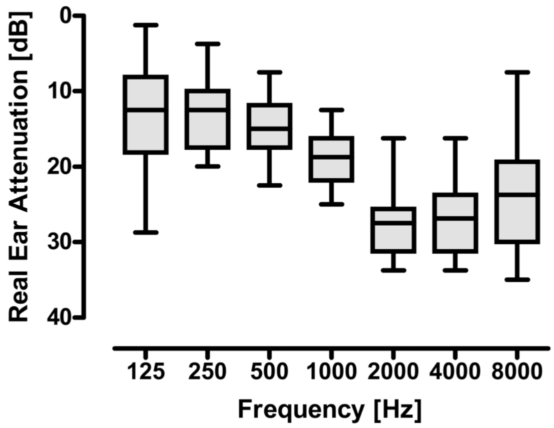

Fig. 2. Attenuation results for EM at each octave band in Real Ear Attenuation at Threshold test (n=20).

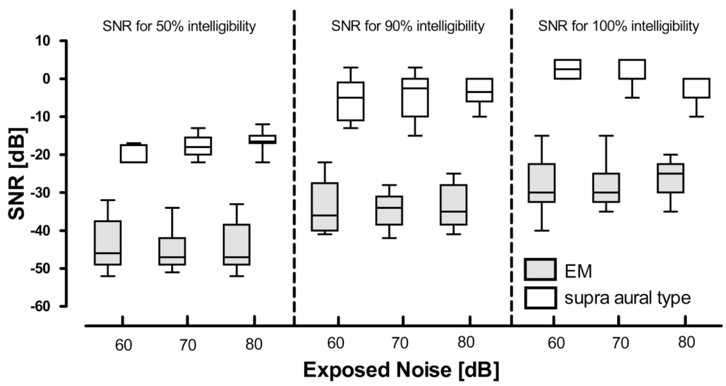

Fig. 3. SNR recorded for 50%, 90%, and 100% monosyllable intelligibility in 60–80 dB noise-exposed environment by type of communication device at speech audiometry (n=10).

university students were chosen, included four males and six females ranging from 19 to 27 in age, with an average age of 22.0 yr[7]. The subjects were asked to wear an EM or a supra aural type headset (FC760A13, Fujitsu Ltd.), headphone type headset, on their left ear and a foam-type earplug (EP-11, Shigematsu) in their right ear.

We presented standardized voice recordings through the EM or the supra aural type headset using the 67-S word list (Japan Audiological Society, 1987) composed of 20 Japanese monosyllables[8] to subjects sitting in the same environment as in the REAT test. The trained examiner manually operated an audiometer (AA-79, RION) at 5 dB steps to obtain a speech audiogram. During testing, we presented pink noise from the loudspeakers at 60, 70, and 80 dB. We calculated the speech to noise ratios (SNRs) for which 50%, 90%, and 100% monosyllable intelligibility was recorded for each subject.

SNR [dB]=hearing level for speech [dB]–pink noise [dB]

We performed ANOVA on a mixed model including subject effect by statistical software (SAS 8.02) to determine the potential effects on SNR of receiver type and levels of exposed pink noise.

Results

The diameters of the ear canals measured with the EARGAGE were compared to the selected ear pad size, as shown in Fig. 1. Figure 2 shows the results for each individual. The attenuation of EM at a given octave band frequency was averaged for all subjects. The NRR of this device was 9.0 dB.

ANOVA indicated that the receiver type significantly affected speech audiometry results (p<0.0001). EM recorded smaller SNR values than the supra aural type at all levels of noise exposure and all levels of monosyllable intelligibility (Fig. 3).

Discussion

It is well known that actual noise attenuation performance does not reach the figures provided by the manufacturer[9)], particularly at lower frequencies[10)] or when subjects receive inadequate instruction[11)]. Although the reasons were not immediately clear, mismatching a particular earplug likely led to lower attenuation levels at lower frequencies.

This study indicates that EM offers significant noise attenuation capacity, meeting the criteria of EP-1 given by the JIS standard[12)], obtained from the subjects in this study were untrained students.

Significant differences in SNR may result from differences in noise attenuation capacity. Comparisons of noise levels inside and outside headphones in REAT tests demonstrated the significant attenuation capacity of EM as well as attenuation of 4.2 to 6.6 dB with supra aural headphones[7)]. This may explain in part the 25 dB of SNR detected with syllable intelligibility. However, further investigation is needed to assess the contributions from other known factors, including acoustic amplification by the external acoustic meatus and the frequency characteristics of the speakers used.

This study indicates that providing telecommunication devices with noise attenuation capabilities may enable communication at voice levels lower than levels of ambient noise. We would add, however, that real noise attenuation in an environment may not perfectly match these results, which were obtained in an environment featuring constant noise levels. Further study is needed to determine whether the application of EM to headsets at work sites can reduce the levels of noise to which workers are exposed.

Additional study is needed to explore the advantages achieved by built-in microphones blocking ambient noise with respect to occupational health issues and effectiveness, including efficient voice sensing and transmission, compared to ordinary microphones hanging or fixed in front of the individual's mouth.

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