Can an inactivated hearing aid act as a hearing protector?

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According to the jurisprudence on discrimination due to hearing impairment, any assessment of employability must take into account to what extent a hearing aid may restore hearing capabilities [1]. In noisy working environments, the possibility of further hearing loss due to amplification of the ambiant noise through the hearing aid should then be considered. This potential damage could possibly be controlled by turning the hearing aid off during noisy periods and turning it on to facilitate communication during quiet intervals. However, little is known about the effectiveness of hearing aid earmolds as ear protectors when the aid is inactivated.

Only one study has been conducted on attenuation of hearing aid earmolds [2]. The findings showed a mean attenuation of less than 10 dB below 2 kHz with six models of earmolds coupled with a behind-the-ear hearing aid. However, questions concerning the validity of this data can be raised. The subjects were fitted with an aid earmold in the tested ear and with a foam earplug and earmuff on the non-tested ear. The influence of the non-tested ear on the hearing threshold measurements in the occluded condition may have contaminated the data. Another source of uncertainty is related to the earmold impressions obtained, based on a comparison of attenuation data from the conventional earmolds (fabricated from impressions) with data from an earmold made out of a foam plug equipped with a tube. The author of the study explains the relatively poor attenuation he measured with conventional earmolds, by the influence of leaks around the molds when inserted in the ear. It has indeed been shown that a difference of only 0.5 mm between measured ear canal dimensions and earplug size exert a considerable effect on the sound pressure level in the ear canal [3]. Furthermore, there are other factors that need to be investigated, such as earmold venting, length of the earmold canal, and earmolds of in-the-ear and in-the-canal model of aids. This study was undertaken to assess the effectiveness of various models of inactivated hearing aids as hearing protectors. Insertion loss was measured in a free field using an acoustic head simulator specifically designed for hearing protector evaluation.

Method

Equipment and procedure

Experiments with hearing aid earmolds were carried out in a hemi-anechoic chamber using the acoustic head simulator designed by Kunov and Giguère [4]. This acoustic test fixture (ATF) approximates the physical dimensions and the acoustical eardrum impedance of the median human adult. The ATF includes a mechanical reproduction of the human circumaural and intraaural tissues. The acoustic isolation of the head simulator is greater than the bone conduction limitations to hearing protection.

A pink noise generator (BK-1405) was directed to an attenuator (HP-350D), a power amplifier (BGW-750D) and a loudspeaker (JBL-2445J) coupled with an exponential horn. The ATF, the left ear of which was equipped with the large KEMAR pinna, was facing the horn at a distance of 25 cm. The sound pressure level was picked up in the Zwislocki coupler from the left ear of the simulator by means of a condenser microphone (BK-4134) connected with a real time analyzer (BK-2123) by means of a preamplifier (BK-AO009). The ATF was installed on a platform that allowed a 360° rotation.

A wide band noise was presented at an overall level of 100 dB SPL as measured at the center of the ATF position in its absence. The hearing aid earmolds were evaluated in terms of their insertion loss, that is, the difference between the unoccluded ear sound-pressure level and the occluded ear sound-pressure level. Insertion loss was measured in third-octave bands between 0.125 and 8 kHz, with the hearing turned-off.

Three types of hearing aids, behind-the-ear (BTE), in-the-ear (ITE) and in-the-canal (ITC) aids were tested. The BTE was a Phonak PICO C-S-T aid, the ITE was a Starkey CE7 and the ITE, a Starkey INTRA III aid. The influence of the following factors was investigated: the type of aid, the effect of venting, the type of earmold associated with a BTE aid (inlcuding the shape, the material, the length of the earmold canal). The interaction between these factors and the horizontal angle of sound incidence was also examined.

Reliabitity of insertion loss measurements

The standard error of measurement (Se) has been assessed by replicating the insertion loss measurements with the three models of unvented aids. Se amounted to ±1.5 dB on an average across different frequency bands. The reproducibility of earmold properties was appraised by replicating the impressions and ordering, on two separate occasions, lucite earmolds for a BTE aid at a earmold laboratory. The difference in measurements of insertion loss from these two earmolds was smaller than 3 dB in any frequency band.

Results

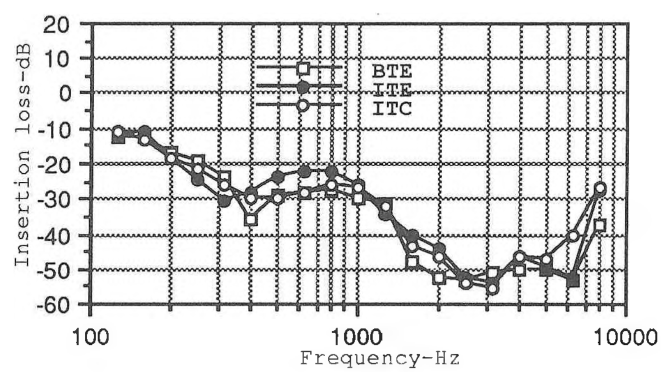

Figure 1. Insertion loss from unvented earmolds of three types of hearing aids measured with a 100 dB SPL wide spectrum noise at azimuth 0°.

Figure 1 compares insertion loss from the three types of aids tested. With all three types, insertion loss values come close to bone conduction limitations to hearing protection in the 1.5-6 kHz band. It drops to 25-30 dB between 0.3 and 1 kHz and to 13 dB or less below 0.2 kHz. The amount of insertion loss is maximal at 0° incidence of incoming noise. It is minimal at 270°, with a drop of 20 dB at 0.8 kHz.

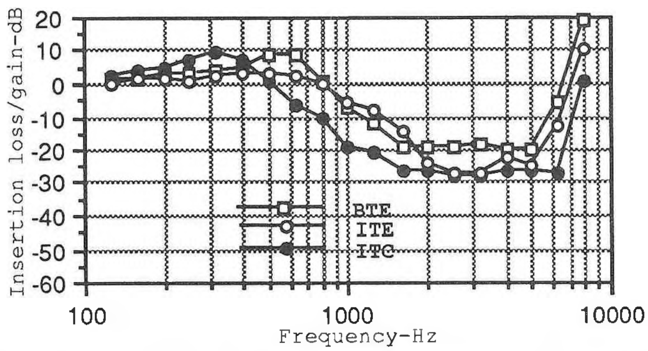

Figure 2. Insertion loss from vented earmolds of three types of hearing aids (vent diameter: 1/8", 1/8" and 1/16" for the BTE, ITE and ITC respectively).

As shown in Figure 2, when the earmolds are vented, insertion loss is considerably reduced in the mid-frequencies and amplifications occur in the lower and higher frequencies. Even a small diameter vent makes an inactivated hearing aid a poor hearing protector at frequencies below 1 kHz. Amplification of the ambiant noise has been measured with a vent diameter as small as 1/32". As expected, our data shows that the smaller the diameter of the vent, the lower the frequency of maximum amplification.

Comparison of a skeleton with a shell earmold of a BTE aid showed insertion loss differences smaller than the error of measurement. The length of the shell earmold canal had no significant influence on insertion loss as long as it extended to 0.8 cm. The material used to make the earmolds affected insertion loss to a certain degree. Silicone was compared to lucite using shell and skeleton molds. The silicone molds gave less insertion loss across the whole frequency range tested. But the difference varied when making the comparison with two shapes of molds, presumably because of a variation in the density of the silicone. This observation raises questions about the reliability of this material when used for earplugs.

A comparison between insertion loss of earmolds and standardized real-ear attenuation at threshold (REAT), measured with conventional hearing protection devices [5], has been made using the Schroeter and Poesselt model [6]. It provides corrective factors for insertion loss measurements that take into account the effect of bone conduction and of the physiological masking artifact of the REAT procedure as well as the occlusion effect of earplugs. The corrected insertion loss values thus obtained show a close correspondance with the mean attenuation data collected in standardized laboratory conditions with conventional hearing protectors.

Table I presents corrected insertion loss results for molds of three types of hearing aids, an E-A-R foam plug with a plastic tube coupled with a BTE aid, and a standard E-A-R foam plug. The corrected insertion loss values for the plug are within 2 dB of those reported by Giguère and Kunov [7], except at 6 and 8 kHz. The discrepancy at these frequencies is explained by free-field measurements in the present study as opposed to diffuse field in the other investigation. The data in Table I indicates that inactivated unvented hearing aids could act as effective hearing protective devices. Sound attenuation should be comparable to or even greater than a well-fitted foam plug above 0.25 kHz. In the lower frequencies, corrected insertion loss values are closer to those reported for earmuffs [7].

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Table I. Corrected insertion loss values (dB), measured in a free field at an angle of sound incidence of 0°, for four types of hearing aid earmolds and a conventional foam earplug.

Frequency Hz	BTE Lucite shell	ITE	ITC	E-A-R earmold +BTE	E-A-R plug
125	10.2	9.2	9.3	7.3	19.6
250	17.2	19.3	22.0	11.6	27.6
500	27.2	27.7	21.5	16.4	27.6
1000	30.1	26.8	26.3	29.6	31.3
2000	52.5	46.4	44.2	33.0	36.4
3150	51.0	55.3	54.3	46.1	45.4
4000	50.2	46.7	46.2	39.2	45.8
6300	53.2	40.2	52.8	42.2	37.8
8000	37.0	26.6	27.3	29.4	34.8

Discussion

According to the present results, BTE, ITE and ITC hearing aids can be used as effective hearing protective devices when turned off. This should be the case, however, only if the mold is unvented and if it is fitted optimally. This latter condition implies excellent impression quality and reliable earmold production. As reported above, silicone molds may have inadequacies in this respect, but a more thorough investigation would be needed on this question.

Although a BTE aid can be coupled with a foam earplug equipped with a tube, for sound attenuation purposes, it is preferable to use a conventional lucite shell or skeleton earmold (Table I).

REAT measurements are considered an accurate indication of the effectiveness of optimally fitted hearing protective devices [5]. The corrected insertion loss results obtained in the present study provide satisfactory estimates of mean REAT data [7]. The present results should thus provide a correct estimate of the sound attenuation that hearing aid users can expect if they wear a properly fitted mold. In light of our findings, a hearing impaired worker could indeed use a passive hearing aid to protect him/herself when the ambiant noise is excessive.

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