The Effect On Sound Attenuation Provided By Earmuffs Of Other Safety Gear Worn In Combination

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1.0 Introduction

The purpose of this study in progress is to determine whether the sound attenuation afforded by hearing protective earmuffs is compromised, if the muffs are worn in combination with other safety gear. The safety equipment of interest are those devices which are worn in close proximity to the head. Combined usage of such devices has the potential of compromising the seal between the muff and the outer ear, resulting in noise leakage under the earcup. The objectives of the present research are to assess attenuation and speech understanding in subjects wearing a Class A muff[1] mounted on a hard hat, either worn alone or in combination with commonly used safety glasses and/or an air-purifying half-mask respirator, relative to unoccluded listening.

There is virtually no information in the literature on the effect on hearing protector attenuation of other safety equipment worn in combination.[2,3] The Canadian Standard on hearing protection[1] cautions, in an appendix, that "the type of protector that best suits a person will depend upon other equipment he must wear." However, there is no documentation of the possible outcomes. As well, the consequences, and possible interactive effects of other factors such as the gender of subjects, their hearing status, and age, have not been well researched. Subject factors have been shown to influence both the attenuation of hearing protectors (worn alone) and auditory performance measures in noise.[4-8]

2.0 METHODS AND MATERIALS

2.1 Experimental Design

Seventy-two working-aged adults (36 males and 36 females) are being tested. Each gender group comprises 12 normal-hearing subjects, 18-39 years of age, and 24 subjects, 40-65 years of age, half of whom will have normal hearing and half, moderate bilateral high-tone sensorineural hearing loss, characteristic of noise-induced hearing loss. Each subject is tested under five listening conditions: (1) with the ears unoccluded-UN, (2) with Class A muffs attached to a hard hat-M, (3) with the muffs and safety glasses-MG, (4) with the muffs and an air-purifying half-mask respirator-MR, and (5) with the muffs, safety glasses and respirator-MGR. All the devices are fit by a trained technician.

Within each condition, measurements are made of (1) free-field hearing thresholds in quiet for eight one-third octave noise bands centred at frequencies from 0.25 kHz to 8 kHz, and (2) consonant discrimination (75 dB SPL) in quiet and in a continuous background of 80 dB SPL speech spectrum noise. Attenuation is derived by subtracting the unoccluded from the occluded hearing threshold for each frequency, within each of the protected conditions.

2.2 Subjects

The study is open to individuals who are fluent in English. Prospective candidates are screened for a history of head injury, systemic disease and neurological disorders. Those whose health status does not preclude participation are invited for a hearing screening test. Headset hearing thresholds are measured in each ear at two pure-tone frequencies, 0.5 kHz and 4 kHz. Those with thresholds in both ears equal to or less than 20 dB HL[9] are admitted to the normal-hearing groups. Those over the age of 40 years with thresholds of 25-50 dB HL at 4 kHz and normal hearing at 0.5 kHz in both ears are admitted to the groups with hearing loss.

2.3 Apparatus

The apparatus has been previously described in detail.[10] Subjects are tested individually within a semi-reverberant sound proof booth (3.5m by 2.7m by 2.3 m) that meets the requirements for hearing protector testing.[11] Pure-tone stimuli used for hearing screening are generated by a Hewlett Packard multifunction synthesizer (HP 8904A), and presented monaurally over a Telephonics TDH-49P headset. One-third octave noise bands for the experimental hearing threshold task are generated by a Bruel & Kjaer noise generator (B&K 1405) and band pass filter (B&K 1617). The speech test is commercially available on audio cassette and is played by a Yamaha twin cassette deck (KX-W900/U). The stimuli for the latter two tasks are presented free-field over a set of three loudspeakers (Celestion DL10) positioned to create a uniform sound field. Stimulus selection and fine adjustment of stimulus level, duration and envelope shaping are accom-plished by means of a Coulbourn Instruments modular system. The output will be fed to a pair of manual range attenuators (HP 350D) and Rotel mixer amplifier (RA 1412). For the measurement of hearing thresholds, subjects signify their responses by means of a hand held push-button switch. Paper and pencil are used for the consonant discrimination task. Devices are controlled from a personal computer (AST Premium 286) via IEEE-488 and Lablinc interfaces, and digital I/O lines.

2.4. Procedure

Hearing thresholds are measured once for each of eight one-third octave noise bands centred at frequencies ranging from

0.25 kHz to 8 kHz, using a variation of Bekesy tracking.[9] For each threshold determination, the stimulus is pulsed continuously at a rate of 2.5 per second. The pulse duration is 250 ms, including a rise/decay time of 50 ms. Subjects depress an on/off push-button switch whenever the pulses are audible, and release the switch when they can no longer be heard. The sound level of consecutive pulses is increased in steps of 1 dB until the switch is depressed and then decreased at the same rate of change until the switch is released. A trial is terminated after a minimum of eight alternating intensity excursions with a range of 4 to 20 dB. Hearing threshold is defined as the average sound level of the eight final peaks and valleys. The unoccluded condition is presented first, followed by the four protected conditions in random order.

Speech understanding is assessed using the Four Alternative Auditory Feature Test (FAAF) of consonant discrimination.[12] The subject is given a type-written list of 80 sets of four common monosyllabic words in the form of consonant-vowel-consonants. Half the sets contrast the initial, and half the final consonant (eg., wet, bet, get, yet OR bad, bag, bat, back). One word from each set is presented over the loudspeakers, and the subject circles the alternative heard. Five different lists are available on audio cassette. These are counter-balanced across the five ear conditions, in combination with the quiet and noisy backgrounds, and subjects within groups. The unoccluded condition is presented first, followed by the four protected conditions in random order.

3.0 Results and Discussion

To date, half the subjects have been tested. Nested analyses of variance (ANOVA) were applied to the attenuation and consonant discrimination data sets, respectively, obtained for the twelve subjects in the younger male and female groups. The results of the ANOVA on attenuation indicated that there were significant effects of the protector condition [$F_{(3,66)}=46.48$, $p<0.0001$], frequency [$F_{(7,154)}=126.49$, $p<0.0001$], protector by frequency [$F_{(21,462)}=7.77$, $p<0.0001$], and gender by frequency [$F_{(7,154)}=2.17$, $p<0.04$]. Post hoc analyses using Fisher's LSD test[13] indicated that from 0.25-1 kHz, the attenuation provided by M was significantly greater than that for MG, MR, and MGR. There was no difference between MG and MR but both exceeded MGR. From 2-8 kHz, the attenuation provided by M was greater than that for MG and MGR. At 4 kHz and 6 kHz, M was also greater than MR. Generally, MR and MG provided more attenuation than MGR but were not consistently different from each other.

The ANOVA on the results of the FAAF test indicated that there were significant effects of the protector condition [$F_{(4,88)}=4.00$, $p<0.005$], background [$F_{(1,22)}=544.38$, $p<0.0001$], and protector by background [$F_{(4,88)}=3.32$, $p<0.01$]. Post hoc comparisons showed that within each of the five protector conditions, the percentage of consonants correctly discriminated was significantly greater in quiet than in noise ($p<0.05$). In quiet, there was no difference to the protector condition. In noise, listening with M, MR or MG resulted in significantly higher scores that did unoccluded listening.. There was no difference due to the various combinations of devices.

The results demonstrated that for young listeners the wearing of other safety gear (glasses and half mask respirator) alone or in combination significantly decreased the attenuation provided by Class A muffs attached to a hard hat. The results for males and females did not differ. Mean attenuation values achieved by both groups were within 7 dB of the manufacturer's specification, indicating that a good fit had been achieved. The results observed for the consonant discrimination task were similar to those reported previously.[6] The use of the muffs in noise proved beneficial relative to unoccluded listening. The decrease in attenuation when other safety gear were worn was not sufficient to diminish this effect.

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