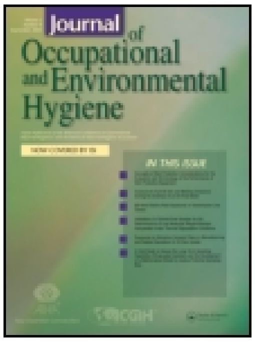

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Evaluation of Noise Attenuation and Verbal Communication Capabilities Using Three Ear Insert Hearing Protection Systems Among Airport Maintenance Personnel

Lisa Wagoner, James McGlothlin, King Chung, Elizabeth Strickland, Neil Zimmerman, and Gary Carlson

School of Health Sciences, Purdue University, West Lafayette, Indiana

The goal of this project was to determine whether one type of earplug would allow a user to hear communication in a noisy environment better than two other types of earplugs. The three types of earplugs studied are newly available on the market. Sonomax SonoCustoms are custom fitted to the user. E-A-R Push-Ins are the newest form of foam earplugs, and Howard Leight SmartFits have an adaptable shape. One of the earplug manufacturers claimed to have improved verbal communications due to the design of the earplug. We hypothesized that the type of earplug providing better communication properties would have lower attenuation around the communication frequencies compared with the other types. To test this hypothesis, we used speech intelligibility and attenuation tests in the laboratory on 26 subjects, and real-time video exposure monitoring in the field (airport maintenance personnel) for visual communication cues. ANCOVA was used to analyze the data from the laboratory study. The type of earplug worn was not significant in the model (p-value 0.0849), nor was attenuation of the earplug (p-value 0.2379). Further analysis showed that attenuation did not differ significantly among earplugs (p-value 0.5903). Logistic regression was used to analyze the data from the field study. Again, the type of earplug was not significant in the model (p-value 0.0965). A comfort questionnaire determined that Howard Leight SmartFits and the E-A-R Push-Ins were more comfortable and easier to use than the Sonomax HPDs (p-value <0.0001). We found a definite difference between manufacturers' attenuation data and our attenuation data, especially in the frequencies for 125–1000 Hz. Also, there was no difference in frequency and overall attenuation among the HPDs. This resulted in no difference in communication abilities among the types of HPDs.

Keywords airport, attenuation, communication, earplugs, hearing protection devices

Address correspondence to: Lisa Wagoner, Purdue University, School of Health Sciences, 550 Stadium Mall Drive, Room 1263F, West Lafayette, IN 47907; e-mail: lwagoner@neo.rr.com.

INTRODUCTION

Excessive noise is a prevalent problem in the workplace today. Earplugs, or hearing protection devices (HPD), are used prevalently in the workplace to protect workers' hearing. If a worker is trained properly, and the earplug is worn correctly, earplugs can reduce the level of noise entering the ear canal, thus reducing the possibility of noise induced hearing loss (NIHL). Although earplugs help attenuate unwanted noise, they can also impair vital communications, especially in potentially hazardous occupations. Vital communications can be anything from warning signals that require the worker to be able to respond, co-workers and/or supervisors who speak to the worker, or even something as simple as the sound of a machine not working properly.

For safety reasons, there has been a need to evaluate noise exposure and speech intelligibility together as connected issues, especially in high-noise environments.(1) Previous studies have attempted to answer the question of whether earplugs improve speech intelligibility in noisy areas. A study that tested the effect of earplugs on passenger speech reception in rotary wing aircraft found that earplugs will not interfere with the reception of speech and that their use may improve speech reception.(2) Another study found that although hearing protectors do not degrade the speech intelligibility for the wearer, the speaker's verbal communication is reduced in level and quality to such an extent that intelligibility for the listener is also reduced.(3) It was also found that the effect of wearing HPDs on speech intelligibility depended on the level of background noise. Below about 70 dB there is a loss of speech intelligibility, and above about 85 dB it does not cause degradation and may, in fact, cause a slight improvement in speech intelligibility.(3)

The goal of this project was to determine whether there were any differences in communication abilities (hearing communication in noisy environments) between three types of earplugs. The first choice of HPD was the Sonomax SonoCustom (Sonomax, Montreal, Canada) because it is advertised as improving communication ability. Because this product was new, the other two earplugs were chosen because they too were new to the market: E-A-R Push-Ins (E-A-R, Indianapolis, Ind.) and the Howard Leight SmartFit (HLS, Smithfield, R.I).

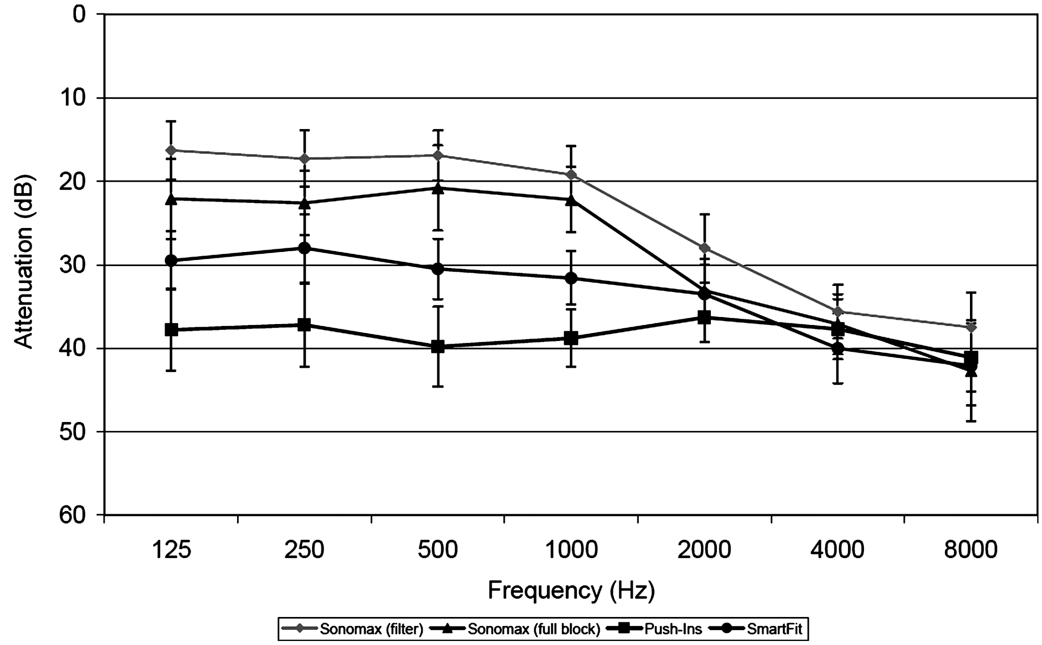

FIGURE 1. Comparison of attenuation by octave band of manufacturer's data for each earplug per ANSI 1974. *Notes:* To see whether differences in attenuation lead to differences in communication abilities between earplugs, it is necessary that the earplugs tested be different in attenuation. A check of the manufacturers' attenuation data shows that between 500 Hz and 2000 Hz (a part of the bandwidth for critical speech intelligibility), these earplugs do differ.

Push-Ins are a type of premolded, foam earplug with an insertion stem that allows them to be pushed into the ear canal instead of being rolled up. Their noise reduction rating (NRR) is 25 dB. The NRR is a single-number descriptor that is used to estimate the overall average noise reduction.[4] The HLS is a soft, premolded type of earplug, and its NRR is also 25 dB. Sonomax are custom fitted to the user. A partial block filter can be inserted in a premolded channel in the HPD that will set the attenuation at a predetermined rate. A full block can also be inserted when higher attenuation is needed. The NRR of the full-block Sonomax is 15 dB. All of the NRR values listed for Sonomax, EAR, and HLS are those claimed by their respective manufacturers and were measured using the ANSI standard S.3.19-1974.[5]

A comparison of the manufacturers' data of the measurement of the NRR across certain frequencies shows a difference in attenuation between HPDs. Figure 1 shows this comparison by octave band. From this graph, it can be seen that if variation in attenuation resulted in differences in communication, then these HPDs would have communication differences. The hypothesis of this study was that the type of earplug that would provide better communication properties would have lower attenuation around the communication frequencies as compared with the other earplugs. The frequency range that is most critical for speech intelligibility is between 600 and 4000 Hz.[4] The aim was to see whether this attenuation difference would be maintained during this study and whether this would lead to differences in speech intelligibility. To test this hypothesis, the three HPDs were evaluated quantitatively and qualitatively in the laboratory and in the field. Speech intelligibility tests were used in the laboratory, and real-time video exposure monitoring (VEM) was used in the field for visual communication cues, which are cues that people might use when verbal communication is not enough.

METHODS

Volunteer subjects were recruited from the maintenance area of two airports. A total of 28 subjects participated in the study; 22 were from American Trans Air (ATA) and 6 were from Purdue University (which has its own airport). All subjects were male and ranged in age from 25–57 years (average of 41.3 years); average length of time on job was 11.9 years. Each subject wore all three HPDs during the lab tests and field trials. Data collection took place in the Audiology and Speech Sciences laboratory at Purdue University and at the airport maintenance bays while subjects performed their normal, routine work procedures.

Due to the type of noise exposure, all workers were fitted with a full block for the Sonomax HPD. Because the Sonomax earplugs were not adjusted for attenuation with their filters, would the workers still receive better communication abilities? Does using the filter in the Sonomax HPD affect the communication ability without regard to how much reduction in attenuation the filter gave? To answer these questions, two types of Sonomax earplugs were tested in the laboratory study, one with a full block and one with a filter. The filter was inserted into each worker's custom fitted earplug during the laboratory study. The filter used for this study is designated as the "yellow" filter and its NRR is one decibel less than the full block. The highest rated filter was used because any increase in communication abilities caused by the properties of the filter would be shown in using any of them; the yellow filter more closely approximated the attenuation properties of the other earplugs tested.

Laboratory Study

The laboratory study was conducted in an anechoic chamber that measures 10 ft high by 5 ft wide by 19 ft long. Eight speakers were placed in a 2 m diameter circle. The subject sat in the center of this circle and faced Speaker 1 at an azimuth of 0°. Speakers 2 through 8 were placed at 45°, 90°, 135°, 180°, 225°, 270°, and 315° azimuth. The examiner conducted all the tests from behind a desk in a corner of the same chamber where the clinical audiometer (GSI 61; VIASYS Healthcare Inc., Madison, Wis.) and computer were placed. Two separate tests were conducted in the laboratory part of the study. These were the real ear attenuation at threshold (REAT) test, used to determine personal attenuation, and the hearing in noise test (HINT), used to determine speech intelligibility in background noise.

REAT Test

The attenuation of the HPDs for each subject was determined by using the REAT test, which is based on the difference between the open and occluded hearing level of a subject. In this study, the subjects inserted the earplugs themselves to more closely approximate the attenuation they would experience in their workplace. All subjects were familiar with the use of earplugs in the workplace and received manufacturers' directions for the insertion of the earplugs. The hearing level determinations were made using pure tones from the clinical audiometer at 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz. The tones were presented to the subject through Speaker 1, which was 1 meter directly in front of the subject.

At each frequency, a tone would be given at a certain hearing level (dB HL). If the subject heard the tone, the next tone would be given at 4 dB HL lower. If the subject did not hear the tone, the next tone would be given at 2 dB HL higher. When the subject had indicated twice that he had heard the tone at a given level as the tones were being increased, that level would be considered his hearing level. After determining the open and occluded hearing levels at each frequency, the calculation below was used to determine the personal attenuation rating (PAR), which is a single number value that represents the individual attenuation for each subject in a laboratory REAT test, as averaged over several octave bands:[6] Note that the PAR is the same as the NRR except that it is computed for each individual instead of from data averaged across subjects, it lacks a 3dB spectral uncertainty correction factor, and it has no standard deviation correction. The spectral uncertainty factor accounts for errors arising from the use of pink noise instead of the actual noise spectrum to which the wearer is exposed. The standard deviation adjustment accounts for the percentage of the population protected.

$$\mathrm{PAR} = 10\log_{10}\sum_{i=1}^{7}10^{\frac{100+C^i}{10}} - 10\ \log_{10}\sum_{i=1}^{7}10^{\frac{100+A^i-ATT^i}{10}} \quad \textbf{(1)}$$

where A^i and C^i represent octave band weighting values for frequency i, and ATT^i is the measured attenuation in dB (difference between the hearing thresholds of the open and occluded ears).[6]

HINT Test

Immediately following the REAT test (before the plugs were removed), a standardized audiology protocol to test speech intelligibility in background noise—the HINT test—was used. This test has been developed to measure the sentence speech reception thresholds (sSRTs), which are the presentation levels of speech necessary for a listener to recognize the speech materials correctly 50% of the time in background noise.[7] Each subject was given different sequences of words in sentence form. Each list was composed of 20 sentences. The sentences were equated for naturalness, length, and intelligibility, and the lists of sentences were phonemically matched and balanced.[7] The sentences used are natural to the English language, and all subjects reported English as their native language. Because speech materials become less difficult with repetition, each subject received a different sentence list when they repeated the test with different earplugs. The background noise was white noise at a level of 85 dB SPL (sound pressure level), the minimum level at which increases in speech intelligibility with HPDs have been found.[3]

The test was controlled through a computer (Dell Intel Pentium 2.4 gHz, 514 MB RAM, Windows XP, Sound Card: Sound Blaster Extigy) with Adobe Audition and Windows Media Player programs. The speech was played from Windows Media Player and directed to the audiometer, which controlled the sound level. Adobe Audition generated the uncorrelated white noise, which was sent to a digital recording system. Both signals were then sent through amplifiers and finally to the speakers. The speech was directed to Speaker 1, whereas the background noise was directed to Speakers 1 through 8. The speech and background noise were calibrated daily using a Type II (Type 2230; Brüel & Kjaer, Norcross, Ga.) sound level meter at the approximate position of the subject's ears.

During the test, the presentation level of the speech was increased or decreased by a fixed amount, depending on the listener's ability to repeat the material correctly.[7] The first sentence was given at a set level for each subject. The first sentence was given at 83 dB to allow for enough room to increase or decrease the sound level. If the subject repeated the sentence correctly, the second sentence was given at a level 4 dB lower than the first. If the first sentence was not repeated correctly, then it was given again at a level 4 dB higher. The first sentence continued to be repeated at successive 4 decibels higher until the subject responded correctly. The subsequent sentences were presented once each, with the presentation level dependent on the accuracy of the preceding response. The first 5 sentences were given at levels 4 dB higher or lower than the preceding sentence, and the last 15 sentences were given at levels 2 dB higher or lower than the preceding sentence. The SRT was estimated by averaging the bracketed presentation levels of the last 15 sentences (6–20). The average SRT was then used to calculate the signal (or speech) to noise ratio, S/N, for each subject's HPD.

Study Design

The design of the laboratory study involved a randomized complete block design. The HINT sentence lists, presented order and experimental conditions were counterbalanced. Assurances were made for a particular list being used for each earplug the same number of times, as well as the number of times it went in a particular order. Using ANCOVA (analysis of covariance) on SAS v 8.02, a comparison of the S/N ratios was performed, with the attenuation of the earplugs used as a covariate. Other explanatory categorical variables included in the model were subject (as a random effect), type of plug, sequence in which the plug was tested, hearing level of the subject, and the HINT list used. The alpha value for significance was at $\leq .05$.

Field Study

A pilot field study was run to determine the types of challenges found in trying to compare the effect of the different HPDs on speech intelligibility in noise. The subjects had been fitted with the Sonomax full blocks, so the filters were not used for this part of the study. The other two types of HPDs included were the E-A-R and HLS. Due to time constraints and ability to access the workplace, four subjects were chosen from the ATA maintenance group of volunteers. The subjects wore each of the three earplugs at different times and in different orders, which were randomized using a table of random digits. A Quest Q-400 dosimeter (Type 2; Quest Technologies, Oconomowoc, Wis.) was worn by the subject. This dosimeter was set up to measure sound levels based on the Occupational Safety and Health Administration (OSHA) hearing conservation monitoring methods with a 1-sec logging rate. A digital video camera was set up just outside the subject's work area to record the job tasks. The clocks on the dosimeter and the video camera were synchronized to match events on the video with their corresponding noise levels. The subjects were monitored for 1.5 hours for each HPD. The videotape of the workers' activities was analyzed for various signs of speech communication difficulties, as in the following list:

1. Removal of earplugs
2. Distance between communicating people at less than one arm's length (<3 ft)
3. Cupping ear with the hand
4. Placing ear next to the mouth of the speaker
5. Increased use of hand gestures
6. Moving conversation to a new, quieter location
7. Shutting off noise source after initialization of conversation
8. Repeated phrases in conversation
9. Requests for clarification
10. Writing

To avoid potential bias, the video was analyzed separately from the dosimeter recorded noise levels. In the video, each conversation was examined and the beginning and stop times were noted and also whether a communication difficulty was present. The times were matched with the noise level from the dosimeter. These levels were averaged over the time period of the conversation using logarithmic averaging.

Because the response outcomes in the field study were binary (whether a difficulty was present during a conversation), the data was analyzed using logistic regression on SAS v. 8.02. The length of conversation, average noise level, subject, and type of plug were used as the explanatory variables.

RESULTS

At the completion of this study the total number of subjects had decreased. One subject lost his Sonomax earplugs but was still willing to be tested with the HLSs and the EARs. Two subjects dropped out. The final design of the study was thus an unbalanced block design of 26 subjects.

Laboratory Study

REAT test

The attenuation of each HPD at a given octave band frequency was averaged over all the subjects. Results are graphed in Figure 2. Using sample contrasts under ANOVA, it was determined that at each octave band frequency the mean attenuations were not statistically different from each other. After calculation of the PAR, comparisons were made between each plug to see whether the same results as those of the octave bands were obtained. Indeed, the PARs were not significantly different from each other.[8]

HINT test

Most subjects did not have much spread in S/N ratios among HPDs. Figure 3 shows the adjusted means (from the ANCOVA model) for each type of plug with 95% confidence intervals included. The lower the S/N ratio, the better was the speech intelligibility. It can be seen that the HPDs are not significantly different from each other in their average S/N ratios. Using an ANCOVA test to show significances, it was determined that type of plug, attenuation, and sequence in which the plug was tested were not significant in the determination of S/N ratio. Subject (p-value <0.0001) was significant. P-values were taken from the Type III sums of squares to account for the unbalanced observations (since two subjects had dropped out of the study). Table I shows the classification of hearing levels used and the number of subjects that fit into each category.

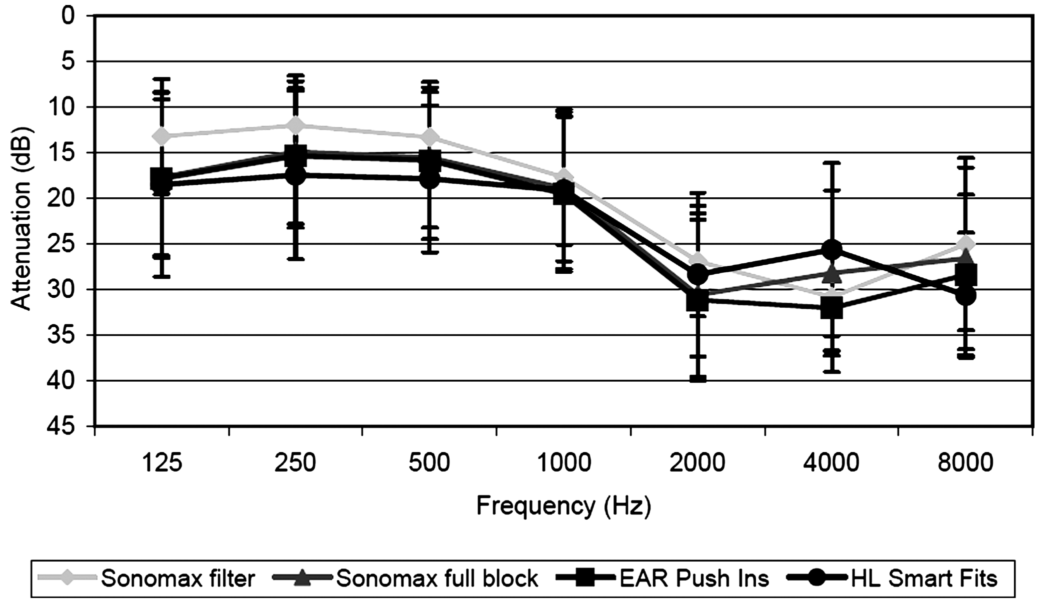

FIGURE 2. Average attenuation results for each earplug at each octave band from this research (n = 26 for E-A-R and HLS, n = 25 for both Sonomax)

Because the hearing level of the subject is tied to each subject, a test was used to see whether it was significant in the model. The variable, hearing level, was nested into the variable, subject, in the model; it was not statistically significant.

Field Study

Conversation and data on the number of difficulties for the four subjects are listed in Table II. Also included are the noise level ranges where difficulties were seen. On first analysis

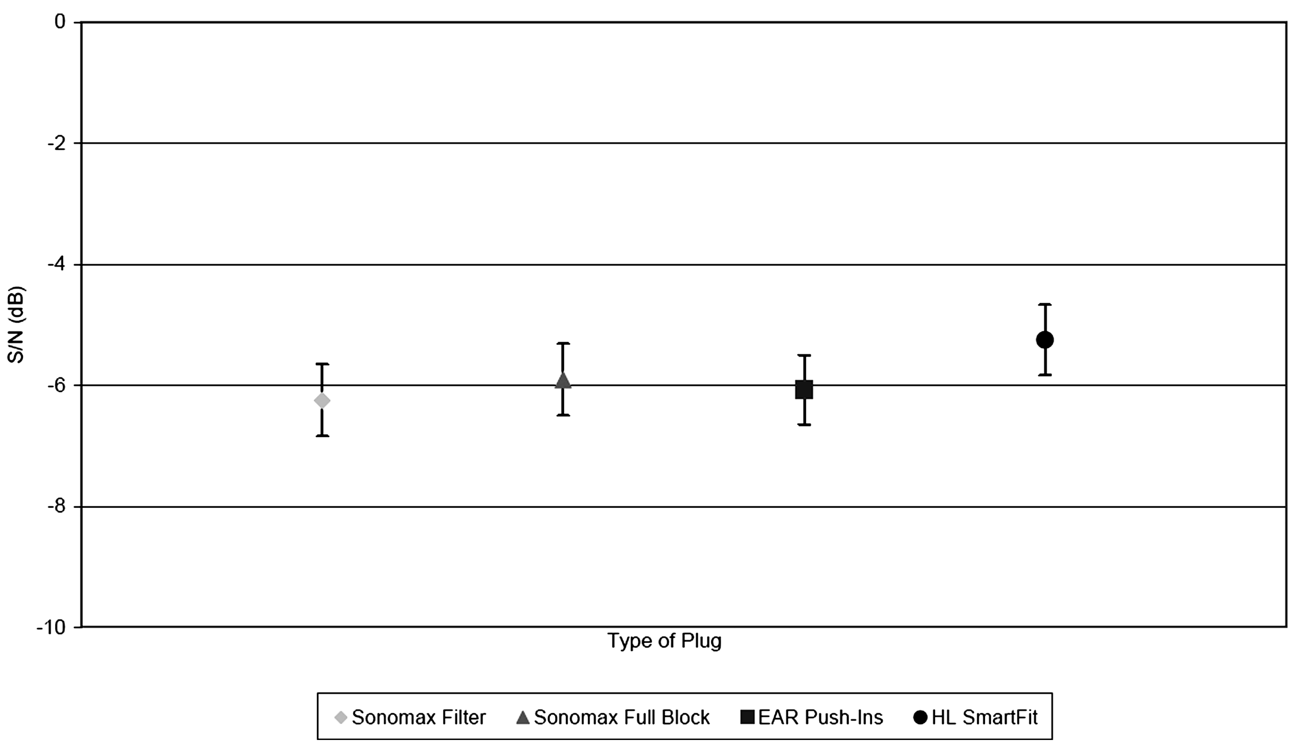

FIGURE 3. Average S/N ratios by type of earplug with 95% confidence intervals. *Notes:* The lower the S/N Ratio, the better the speech intelligibility. The earplugs do not differ significantly in their average S/N Ratios.

TABLE I. Classifications of Hearing Level

Category	Level (dB HL)	Classification	Number of Subjects
1	0–25	Normal hearing	16
2	26–40	Mild hearing loss	7
3	41–55	Moderate hearing loss	1
4	56–70	Moderate-severe hearing loss	2
5	71–91	Severe hearing loss	0
6	>90	Profound hearing loss	0

Note: Hearing level is the average threshold at 500, 1000, and 2000 Hz. Hearing loss classification is applied to each ear separately.

of the field data, most of the data above 100 dB are from the Howard Leight SmartFits when they were used by one particular subject. On further examination, some of the data collected from this subject during the high noise levels were from a riveting task. Conversation between this subject and another worker occurred during lulls between the rivet gun operations. Because the dosimeter was set to slow response, the instrument could not differentiate between the operation of the rivet gun and the short, quiet periods in between. The video showed short verbal exchanges (i.e., such as "go," "good" etc.) between the workers and when the rivet gun was not in operation. Because of the slow response of the dosimeter it did not differentiate between the short rivet gun bursts (i.e., higher noise levels) and the short verbal exchanges (i.e., lower noise levels). For this reason, and because there were few comparisons with Sonomax and E-A-R Push-Ins for the SmartFit above 100 dBA, no data points above 100 dBA were included in the logistic model. The result of this model analysis showed that none of the variables are significant. The probability of having difficulty in a conversation is not a function of which HPD a person is wearing, who is wearing it, how long a conversation is, or the noise level associated with the conversation.

DISCUSSION

Laboratory Study

In the lab study, the statistical analysis of the effect of attenuation on the determination of S/N ratio was not significant. However, a conclusion that attenuation does not effect communication cannot be made here. It was determined that the attenuation of the HPDs in this study do not differ significantly from each other. Because there is no difference between them, they do not affect the outcome of the communication test.

Because the manufacturer's ANSI 1974 data was used as a precursor to this study, a comparison with the attenuation achieved in this study is interesting. There are three major differences between the two data sets. First, the overall attenuation in the results from this research is less than the results from the manufacturers' data. This is reported as a common phenomenon when earplugs are fitted by the subject, as in the case from this study, rather than fitted by an expert, as

TABLE II. Field Study Data

Subject Number[A]	Earplug Type[B]	Number of Difficulties/ Number of Conversations	Noise Level Range for Difficulties (dBA)	Length of Conversation Range for Difficulties
19	Sonomax	1/5 (0.2)	104	12
	EAR Push-Ins	4/15 (0.27)	81–104	12–106
	SmartFit	7/32 (0.22)	76–92	7–27
8	Sonomax	2/13 (0.15)	79–80	26–29
	EAR Push-Ins	6/18 (0.33)	79–95	9–58
	HL SmartFit	6/28 (0.21)	79–97	5–44
12	Sonomax	11/41 (0.27)	85–93	6–100
	EAR Push-Ins	16/51 (0.31)	81–97	7–90
	HL SmartFit	6/52 (0.12)	87–92	9–15
1	Sonomax	4/14 (0.29)	74–89	4–13
	EAR Push-Ins	2/5 (0.4)	71–76	9–70
	HL SmartFit	1/24 (0.04)	85	6
			Total	
All	Sonomax	18/73 (0.25)	74–104	4–100
	EAR Push-Ins	28/89 (0.31)	71–104	7–106
	HL SmartFit	20/136 (0.15)	76–97	5–44

[A] Four subjects were used for the field study; however, their identification number remained the same as in the laboratory study.
[B] The Sonomax listed here is for the full block; the filter was not used for the field study.

TABLE III. Questionnaire Results

Question	Answer	Weight	Total Score[A] (Average)[B] Sonomax	Push-Ins	SmartFit
Overall, how satisfied are you with the earplugs?	Very unsatisfied	1	87	79	90
	Unsatisfied	2	(3.63)	(3.43)	(3.91)
	Somewhat satisfied	3			
	Satisfied	4			
	Very satisfied	5			
	Extremely satisfied	6			
Comparisons between plugs	Much better	5	80	70	90
	Somewhat better	4	(3.33)	(2.92)	(3.75)
	About the same	3			
	Somewhat worse	2			
	Much worse	1			
	Don't have an opinion	0			
At the conclusion of this study, will you continue to wear the earplugs?	Definitely will	2	15	–3	9
	Probably will	1	(0.81)	(–0.48)	(0.07)
	Probably will not	−1			
	Definitely will not	−2			

[A] Total Score is determined by multiplying the weight by the total number of responses for each answer, then summing them for each HPD.
[B] Average is determined by dividing the total score by the total number of responses.

in the case of the ANSI protocol.(9) Second, the data from this study have higher standard deviations than the manufacturers' data. This is also due to the subject fit method. Because an expert fits the earplugs in the manufacturer's study, most of the variation is due to the differences in the ear canals of the subjects. In this study, not only is there the variability in ear canal size, there is also the variability in how each subject fit his earplugs. The third difference is in the frequencies from 125 Hz to 1000 Hz. The data from this study, especially for E-A-R and HLS, are lower in this area than the manufacturers'

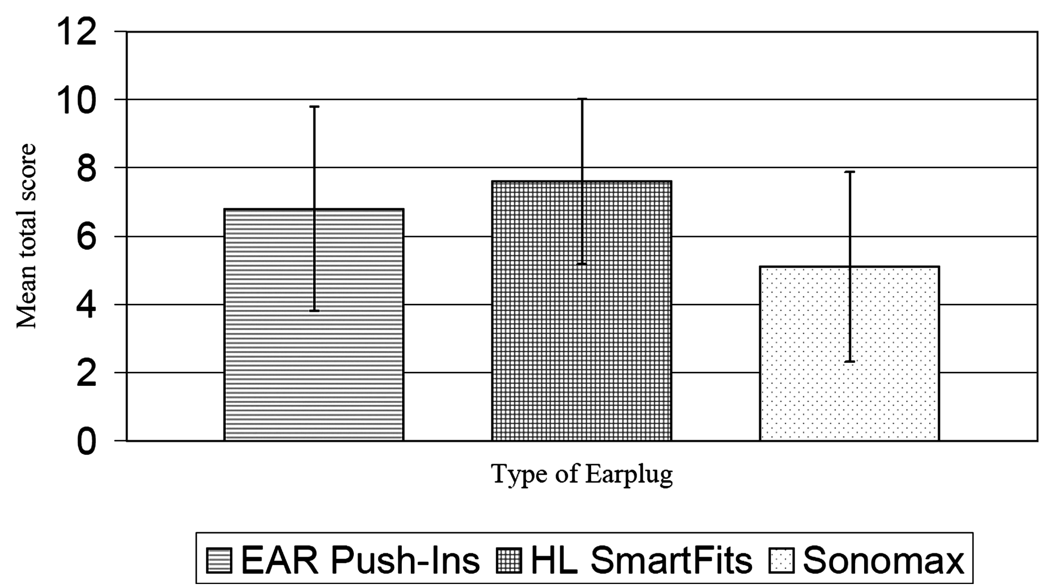

FIGURE 4. Comparison of survey ratings regarding average comfort and ease of use scores. *Notes:* Subjective visual analog scale ratings with standard deviation bars, Comfort at beginning and end of study, and ease of use: scale of 0 to 10, with 0 being Very Uncomfortable/Difficult and 10 being Very Comfortable/Easy. n = 24 (ANOVA $p < 0.0001$)

data. Although the exact reason for this is unknown, the fact that the lower frequencies are harder to control could be a factor. Perhaps, again, this is due to the ability of the subject to get a good fit with the earplug, that is, the better the fit, the better the lower frequencies are attenuated.

Previous studies have shown that people with sensorineural hearing loss do not show a communication benefit when wearing HPDs in noisy environments, even when those without hearing loss do.[10−12] In this study, most of the subjects had either normal hearing or mild hearing loss. Therefore, hearing level was not a factor in this study.

Wagstaff et al.[13] found differences in the levels of speech intelligibility among HPDs. It involved pilots who used HPDs under headsets. They compared foam plugs, custom molded plugs, and "hi-fi" plugs—plugs that have a more even frequency attenuation. Earplugs with different NRR values were used. The foam plug had an attenuation of 30–35 dB with a better attenuation for high frequencies. The hi-fi plug had an attenuation of 15–20 dB with a slightly higher attenuation in the high-frequency range. The custom molded plug had an attenuation of around 15 dB. It was determined that these earplugs gave a better level of speech intelligibility than the other plugs. The explanation for this was that the custom molded plugs gave a more even frequency attenuation at an overall lower amount of attenuation. These other plugs either had more attenuation at the higher frequencies (above 1000 Hz), and thus interfered with the frequencies needed for speech intelligibility, or they had an overall higher attenuation.

However, there are several differences between the Wagstaff study and this one. First, they used a much higher background noise, measured at 104 dB. Second, the earplugs were fitted by an otolaryngologist instead of the subject fit method in this study. A possible third major difference in the two studies was that speech intelligibility was measured using earphones in flight helmet earmuff cups, and such earphones have limitations in the gain they can provide. Limitations in gain, i.e., speech vs. background noise, may result in decreased speech intelligibility.

Field Study

Several challenges in the execution of the field study made the results somewhat difficult to interpret. The objectives were as follows: First, that video exposure monitoring is a viable method to study noise levels; the standard VEM equipment did work well for this study. Second, that the noise exposure in the field was similar to that generated in the lab. The noise that the subjects were exposed to was intermittent, and thus the subjects did not need to wear earplugs all the time. Therefore, unfortunately, the noise exposure did not match between laboratory and field testing. Third, that there were differences in communication abilities among the HPDs in the field. The probability of having a difficulty is not a function of which HPD is worn. Several limitations in the data collection may confound this result. Other variables that could affect the ability of the listener to understand what is being said were not taken into account in this study. Some of these variables include, but are not limited to, the distance between listener and speaker, whether the listener is having difficulty hearing due to the noise levels around him or his inattention to the conversation, and the loudness of the speaker. For the latter, there are two opposing effects on the sound level of speech. First, there is the Lombard effect that states that most speakers raise their voice levels as the background noise levels get higher.[14] On the other hand, because HPDs reduce the level of background noise, one's own voice sounds much louder than when the ears are open (the occlusion effect); therefore, most wearers tend to lower their voice levels substantially.[14] Thus, the combination of lowered voice level because of the use of earplugs, combined with inadequate elevation of voice level to make up for background noise, has major consequences on the ability of earplug wearers to hear and understand each other in noise[14]

Even though similar results were found in the field study as in the lab study, i.e., that there was no difference between HPD types in communication abilities, the several unforeseen limitations discovered as the field study was run, makes it difficult to draw too many parallel conclusions. However, it was determined that given the proper environment, VEM is a viable method to study the effects of a high noise environment. The ability to refer to a video to mark a particular task (in this case, communication difficulty) and then correlate that task to the sound level that the worker was exposed to has great potential and benefits. This could be extended even to noise control projects where worker activity contributes highly to the noise problem.

Limitations

Due to the limitations of the equipment used in the laboratory part of the study, the subjects were tested only at one background noise level of 85 dB for the HINT test. Previous studies have shown that at this level, some increases in speech intelligibility while wearing HPDs have been found.[3] Several limitations on the field study were previously mentioned in the Discussion section. These included additional variables that were not accounted for and a noise source that was not constant. Some of these variables included, but were not limited to, the distance between listener and speaker, the loudness of the speaker, and whether the listener was having difficulty hearing due to the noise levels around him or his inattention to the conversation. Not only was the noise source not constant, most of the time it was generated by the subject. When the subject was not working there was very little noise. His conversations were linked to this cycle. There was very little talking during work, and the work (and thus the noise) stopped whenever they needed to talk.

CONCLUSION

In this study, a difference between manufacturers' attenuation data and the measured attenuation data was found. Also, it was determined that there was no difference in frequency and overall attenuation among the HPDs. This resulted in no significant difference in communication abilities between the types of HPDs in the laboratory study. The results from the field study showed this as well, but these results are limited.

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