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## Acceptance of a Semi-Custom Hearing Protector by Manufacturing Workers

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### INTRODUCTION

Workers complain about wearing hearing protection for two primary reasons: comfort and communication.<sup>(1)</sup> Employers are concerned about hearing protection costs. Recent advances in hearing protector technology seemed to address those issues through a semi-custom earplug. This new device was designed to prevent overprotection by incorporating only enough attenuation to bring the worker down into the safe exposure zone. Although initially more expensive than disposable hearing protection devices (HPDs), the semi-custom hearing protector would be expected to last several years.

The Hearing Loss Prevention Team of the National Institute for Occupational Safety and Health (NIOSH) was invited by a major auto manufacturing company and the union (UAW) to supervise a longitudinal trial of a semi-custom hearing protector (SonoCustom by Sonomax Technologies, Inc., Montreal, Canada). This protector was advertised as (1) being more comfortable since each plug was custom molded for each worker, and (2) more effective because each plug's noise reduction rating was tuned to that worker's particular job. The company's hearing conservation contractor partnered with NIOSH by recruiting volunteers for the study and providing follow-up usage reports. The study was conducted over the course of 1 year with NIOSH site visits at the start, at 1 month, at 4 months, and at 1-year time intervals. The goal of this trial was to determine worker acceptance of the semi-custom earplug.

Compared with the non-custom earplugs used in this study, the SonoCustom ear plugs were relatively new to the market and have not been extensively investigated in the literature. Initial studies have focused on a new way to measure and model the acoustical

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performance.<sup>(2-4)</sup> Wagoner et al.<sup>(5)</sup> studied speech intelligibility and attenuation while subjects wore the SonoCustom earplugs or two other non-custom, commercially available hearing protectors in laboratory tests and in the field. In the laboratory they were not able to find any statistically significant difference, between the three earplugs, for speech intelligibility or attenuation. Regarding comfort issues, they briefly mentioned that the two non-custom HPDs were judged by the workers to be more comfortable and easier to use than the SonoCustom earplug.

## METHOD

Fitting the SonoCustom device began with a trained technician placing a properly sized flexible bladder with an open channel in the subject's ear canals. The bladder is filled with a fluid causing the bladder to expand, harden, and conform to the worker's ear canal, producing the finished custom earplug. The opening through the body of the earplug allows a miniature microphone to be inserted such that the sound level at the medial end of the earplug could be measured for attenuation assessment.<sup>(6)</sup> Using the SonoPass proprietary fit-testing software, broadband noise is played by a computer speaker located in front of the worker, and the predicted personal attenuation rating of the earplug was calculated. After removing the microphone, one of the five attenuating filters, or a "full block," was inserted into the opening. The correct filter is selected to obtain the target attenuation, according to the worker's previously determined daily noise-exposure profile.

### Participants

Of the 224 workers who volunteered to be in the study, 70 were fitted with the semi-custom hearing protector (SHP) (Group A). The other volunteers were divided into two groups, both wearing one of five of the factory-provided earplug hearing protectors. A control group of 82 workers was counseled on the proper wear of the factory-provided hearing protectors (Group B). A pure control group of 72 workers was not counseled until the study ended (Group C).

In addition, about halfway through the trial, the company and union requested that additional semi-custom wearers be added to the study. An additional 65 workers were recruited, 37 of whom were fitted by the hearing protector company (Group S1) and 28 of whom had their plugs made by the plant nurse (Group S2). Thus, we could determine how easily the fitting technology could be transferred.

All volunteers were paid \$50 at the end of the study. The experimental protocol was approved by the NIOSH Human Subjects Review Board for ethical and safety procedures.

### Subject Testing

Each volunteer received a standard industrial hearing test at the beginning and end of the yearlong study. Individual fittesting of the subject's hearing protection occurred during each of the four site visits. As described below, during each visit the volunteers answered questionnaires on hearing protector comfort<sup>(7)</sup> and attitudes and beliefs about working in noise.<sup>(8)</sup> At approximately monthly intervals the hearing conservation contractor would locate wearers of the semi-custom plug and record if the volunteers were wearing the new

earplug. The contractor would inquire about the status of the semi-custom earplugs if the participant was observed not wearing them. The chart in Table I depicts the study design.

### Questionnaires

Participants filled out three questionnaires at different times in the study. A standard Hearing Health History questionnaire asked about ear and hearing problems, including loud hobbies and over-the-counter medications. A Beliefs and Attitudes questionnaire developed by NIOSH<sup>(8)</sup> examined employee beliefs and attitudes about working around noise and wearing hearing protectors. The third questionnaire was a minor modification of the Comfort Index developed by Park and Casali.<sup>(7)</sup> Workers were asked to identify their perceived comfort of the protector based on a five-point evaluation scale (the original index used a seven-point scale) for 14 bipolar word pairs (Figure 1). The word pairs consisted of adjectives such as “painless” and “painful” or “comfortable” and “uncomfortable.” The survey is scored by assigning a “1” to the most comfortable end of the spectrum and a “5” to the most uncomfortable response. Total ratings can vary between 14 (most comfortable) to 70 (least comfortable).

### Attenuation Measurements

The semi-custom protector consistently provided less attenuation than the other earplugs used in this study. This was done intentionally; by using different acoustic filters the manufacturer’s representative could achieve the target protected exposure level of 70 to 85 dBA for a given employee. Figure 2 depicts the earplugs’ attenuation in terms of achieving the ideal amount of protection. Overall, a small percentage of the subjects’ ears were underprotected according to the analysis of their exposures and estimated protection. The majority of the non-custom earplug users were overprotected, while those wearing the semi-custom device had the least number of ears being overprotected. Subjects wearing the semi-custom earplug consistently had the largest percentage of ears falling in the ideally protected category. Median values for the semicustom earplug increased from about 17 to 21 dB over the course of the four test sessions. The initial filter installed in the semi-custom earplug was selected based on predicted job exposure; however, workers accustomed to the greater attenuation of the other protectors tended to request the “full block” maximum attenuation. The increased attenuation observed for the semi-custom device was a result of which of the acoustic filters was inserted into the sound bore of the protector.

### Observations of Semi-Custom Earplug Usage

Observations of workers wearing the semi-custom plugs are presented in Table II. Month 5 was the first month that included the secondary study participants, so the study population of semi-custom earplug users increased from 57 to 114. Generally, fewer than half the workers originally fitted with the semi-custom devices were wearing them when observed at work on the plant floor at any time during the year-long study duration.

A general trend of decreased use was observed as the study progressed. The final observation showed only 25% of the workers who could be located were still wearing the semicustom earplugs. Note that due to changing work schedules and planned/unplanned

absences, not all study participants could be observed each time a walk-through survey was conducted. In addition, some workers left the study for unspecified reasons.

## OVERALL FINDINGS

Surprisingly, the semi-custom hearing protectors were not rated any more comfortable than the standard plant-provided earplugs. Keeping in mind that a lower comfort index indicates a more comfortable hearing protector, the semi-custom earplug was less comfortable (i.e., had a higher comfort index), when compared with the disposable hearing protectors, whether the worker was counseled or uncounseled. As shown in Figure 3, all three semi-custom user groups (Groups A, S1, and S2) judged the semi-custom protector less comfortable than the standard plant-provided non-custom earplugs.

The SonoCustom earplugs were met with much anticipation at the outset; however, workers' enthusiasm for these devices did not continue. Before the NIOSH field team had completed the first site visit, a small number of workers had returned their plugs. Their immediate complaints centered on comfort and perceived lack of attenuation. In all cases where comfort was an issue, new plugs were made. Other concerns were the physical (e.g., cold/wet) sensations associated with the lubricant that the manufacturer suggested using until the worker became more experienced with inserting the earplugs.

This study revealed small but statistically significant differences in comfort index ratings among the different subject groups. The semi-custom protectors were accepted less readily than the non-custom plant-provided earplugs. At the end of the yearlong study only about 25% of the original users were still using their new semi-custom protectors, while those who continued wearing them for the full year indicated that they really liked the earplugs.

An attempt was made to determine whether any questions on any of the questionnaires could predict those workers wearing the semi-custom hearing protectors at the end of the year. The best predictor of wear at 1 year was a high tolerance on the "tolerable-intolerable" scale of the comfort survey. When each of the 10 composite variables on the Attitudes and Beliefs questionnaire was modeled separately as a predictor of HPD use, none showed a statistically significant effect.

Providing custom-molded earplugs will likely increase the cost of administering a hearing loss prevention program, at least for the short term when the initial purchase takes place. Therefore, it may not make fiscal sense to fit an entire worker population if the end result will be a 25% acceptance rate. However, it might be economical if there was some way to identify traits that would allow hearing conservationists to fit only those 25% who will continue to wear the new plugs. Since the semi-custom hearing protectors used in this study are designed to last several years, a cost-benefit analysis might prove that these devices are, in fact, a viable option if their usage/acceptance can be predicted in advance.

Some workers felt that the semi-custom HPDs were not providing enough attenuation, despite fit-test evidence to the contrary. This resulted in requests for "full blocks" (i.e., increased attenuation filter elements) or for workers to resume using their old earplugs. A possible explanation for this might be that the workers have become habituated to being

overprotected. In fact, standard operating procedures in the plant acknowledged that wearing earplugs could interfere with speech communication: one policy was that no production changes could be made unless the supervisor wrote it down.

Had this study been conducted with new workers inexperienced with both hearing protector use and working in noise, the outcome may have been different. Subjects might not have requested greater attenuation for their custom-molded earplugs and more readily accepted the prescribed filter. It is also possible that the impulsive noise environment in the metal stamping plant is not ideal for the semi-custom hearing protectors that were evaluated. Some of the workers who were fit with the custom-molded HPDs complained that noise impulses from the stamping presses startled them or caused them to jump while wearing their new earplugs. Such anecdotal evidence suggests that performing this same study in a more continuous noise environment might yield different outcomes with respect to the acceptance rate.

A similar study should be conducted with a cohort of workers having less experience using hearing protectors. The majority of the population studied in this investigation had been long-term users of hearing protection (mean use was 20 years). As a result, workers already had significant experience and were probably biased against the lower attenuating semicustom device. An additional bias could be against the way the custom earplug felt in the ear canal and that, for the first several uses, subjects had to lubricate the earplug to facilitate proper insertion. Thus, if an inexperienced cohort of hearing protection users could be identified, then repeating this study may reveal different outcomes.

Another point to keep in mind is that total acceptance of the semi-custom device would not have altogether eliminated the need to purchase disposable earplugs. During the study we found some workers who lost or damaged one or more of the semi-custom devices or left them at home or in the car. The worker would have to wear disposables until a new device could be fabricated by the manufacturer's representative or until the plugs could be retrieved. Also, visitors to the plant would have to be provided with standard hearing protection.

In summary, the present study reinforces past research that shows that workers given a wide selection of HPD choices are more likely to wear hearing protection. Unfortunately, those factors influencing acceptance and usage are not completely understood. Additional research is needed to fully investigate the role of earplug comfort when selecting hearing protectors or assessing their usage in noisy work environments.

A full report of this study is available on the NIOSH website as a web document<sup>(9)</sup> <http://www.cdc.gov/niosh/surveyreports/pdfs/ECTB-312-11a.pdf>.

## ACKNOWLEDGMENTS

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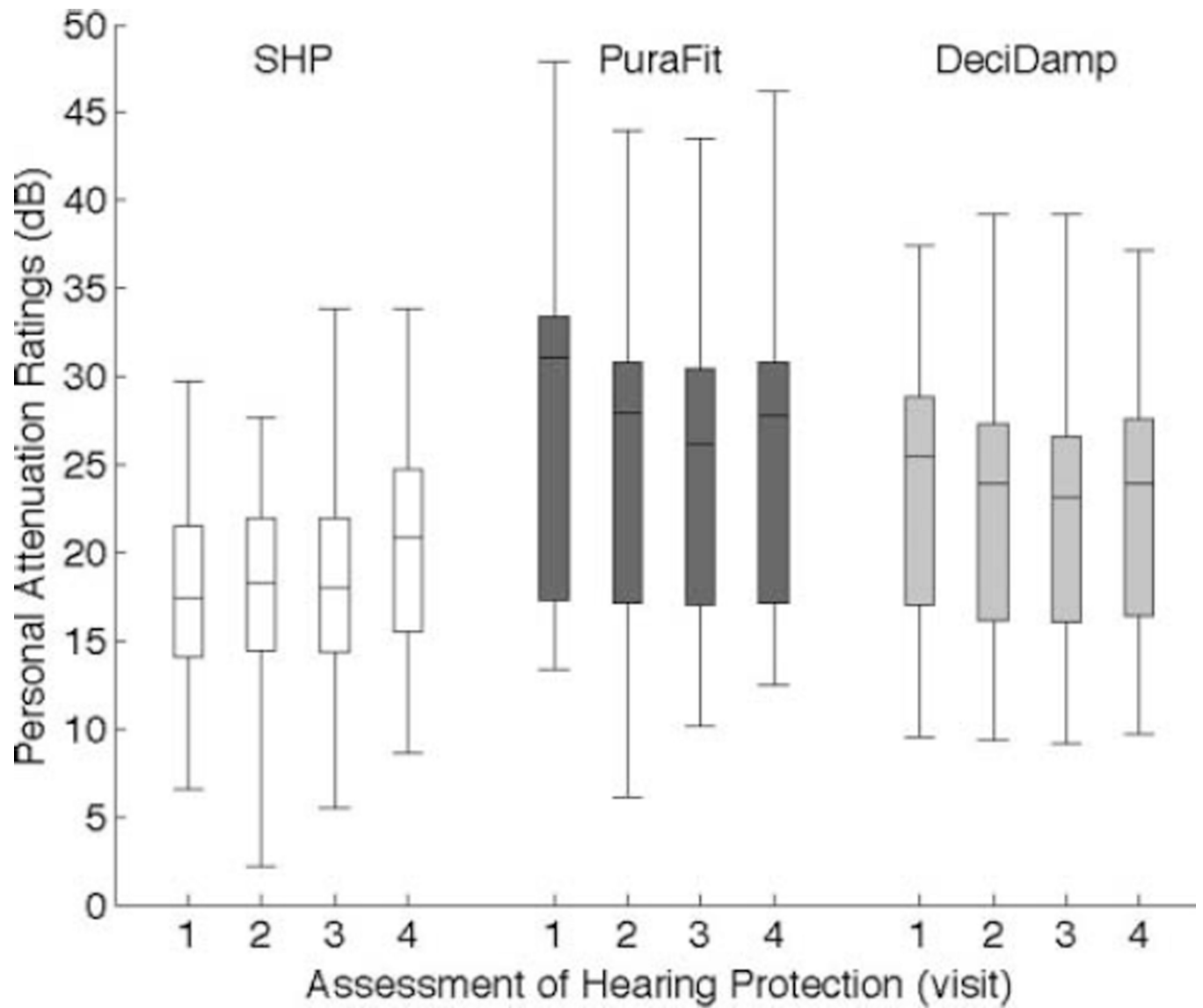
This questionnaire asks about the comfort of the protector you are currently wearing. Each line contains a word pair that consists of opposites. You are asked to place a check or x in one of the five boxes that best describes the comfort of your protector along that line.

HOW DOES THE HEARING PROTECTOR FEEL NOW?

Painful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Painless
Comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Uncomfortable
Uncomfortable Pressure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Not Uncomfortable Pressure
Tolerable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Intolerable
Loose	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Tight
Bothersome	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Not Bothersome
Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Heavy
Not Cumbersome	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cumbersome
Hard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Soft
Hot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cold
Rough	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Smooth
No Feeling of Complete Isolation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Feeling of Complete Isolation
Ear Blocked	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ear Open
Ear Full	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ear Empty

**FIGURE 1.**

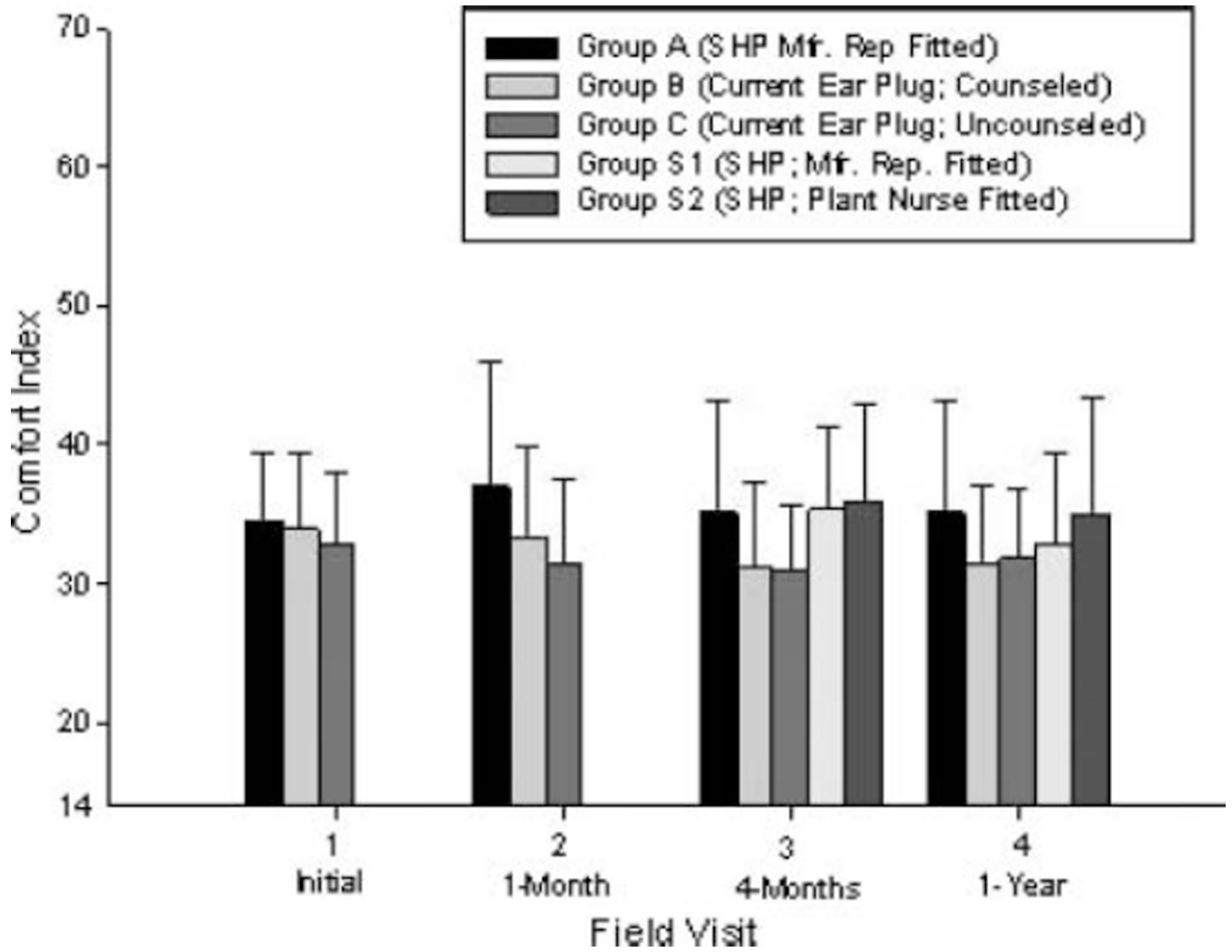
Questionnaire used to compute the Comfort Index (adapted from Park and Casali, 1991<sup>(7)</sup>)



**FIGURE 2.**

Personal attenuation ratings for three earplugs. The semi-custom hearing protector (SHP) trends to greater personal attenuation ratings (PAR) as time passes and workers requested greater attenuation. The Pura-Fit and DeciDamp (two foam earplugs provided by the facility) PARs remained relatively stable over the course of the year. The two foam earplugs also provided greater attenuation than the semi-custom hearing protector.





**FIGURE 3.** The Comfort Index for the HPDs worn in this study. A lower number indicates greater comfort.

**TABLE I**

## Design of the Study

Group	Site Visit			
	Initial Visit (#1)	1 Month (#2)	4 Month (#3)	1 Year (#4)
<b>A</b> (SHP –fitted by mfr. rep.)	HHQ, BAQ, ComfQ, Audio, FIT, Coun.	BAQ, ComfQ, FIT	BAQ, ComfQ, FIT	BAQ, ComfQ, Audio, FIT
<b>B</b> (Current HPD; counseled)	HHQ, BAQ, ComfQ, Audio, FIT, Coun.	BAQ, ComfQ, FIT	BAQ, ComfQ, FIT	BAQ, ComfQ, Audio, FIT
<b>C</b> (Current HPD; not counseled)	HHQ, BAQ, ComfQ, Audio, FIT	BAQ, ComfQ, FIT	BAQ, ComfQ, FIT	BAQ, ComfQ, Audio, FIT, Coun.
<b>S1</b> (SHP–fitted by mfr. rep.)	N/A	N/A	HHQ, BAQ, ComfQ, Audio, FIT, Coun.	BAQ, ComfQ, Audio, FIT, Coun.
<b>S2</b> (SHP–fitted by plant nurse)	N/A	N/A	HHQ, BAQ, ComfQ, Audio, FIT, Coun.	BAQ, ComfQ, Audio, FIT, Coun.

*Notes:* HHQ, Hearing Health Questionnaire; BAQ, Beliefs and Attitudes Questionnaire; ComfQ, Comfort Questionnaire; Audio, audiogram; FIT, fit test; Coun., Counseling by audiologist; N/A, Groups S1 and S2 not enrolled in study until third visit.

TABLE II

Observations of Study Participants Wearing Semi-Custom Hearing Protectors

Month	Number of SHP Wearers Enrolled in Study	Number of SHP Wearers Observed	Number Wearing SHP	Number not Wearing SHP	Percent of Observed Participants Wearing SHP (95% CI) <sup>A</sup>	Percent of Participants not Observed
2	57	46	20	26	43% (29, 57)	19%
3	57	44	11	33	25% (12, 38)	23%
5	114	88	18	70	20% (12, 28)	23%
6	102	90	21	69	23% (14, 32)	12%
7	100	75	20	55	27% (17, 37)	25%
8	99	76	28	48	37% (26, 48)	23%
10	93	75	19	56	25% (15, 35)	19%
11	93	64	16	48	25% (14, 36)	31%

<sup>A</sup> Lower and upper values for the 95% confidence interval shown in parentheses.

*Note:* A second cohort of semi-custom earplug wearers was added at Month 4, causing an increase in the enrolled workers beginning with the following observation (see text). The wearing status of all study participants was not observed each month.