Development of APHAB Norms for WDRC Hearing Aids and Comparisons with Original Norms

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Objectives: This study was undertaken for two purposes: First, to provide a comparison of subjective performance and benefit measured with the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire for two groups. One group included hearing-impaired individuals using 1990s-era linear processing hearing aids. The other group included hearing-impaired individuals using more current wide-dynamic range compression (WDRC)-capable hearing aids fit using current practice protocols. The second purpose of this study was to determine whether APHAB norms derived from scores for current hearing aid users were different from the original 1995 norms. It was hypothesized that technology improvements would result in improved subjective performance for modern hearing aid wearers.

Design: A systematic sampling method was used to identify and recruit subjects from seven private-practice audiology clinics located across the United States. Potential subjects were limited to older hearing-impaired individuals who were wearing hearing aids capable of WDRC processing. One hundred fifty-four subjects returned completed APHAB questionnaires. Participants reported mostly moderate to moderately severe subjective hearing difficulty.

Results: No differences in perceived difficulty with speech communication were observed between the two groups. However, aversiveness of amplified sound was less frequently reported for users of WDRC-capable hearing aids. Norms were generated using data from all of the operationally defined successful hearing aid users in the sample and compared with the original 1995 norms. Differences between the 1995 and 2005 norms were minimal for the speech communication subscales. However, the 2005 group consistently reported less frequent difficulties with sound aversiveness (AV subscale) in the aided condition. In addition to these findings, an improvement was observed in the rate of successful adjustment to hearing aids between 1995 (43%) and 2005 (82%).

Conclusions: Overall, problems understanding amplified speech did not decrease in frequency when hearing aids transitioned from linear to compression processing; however, the compression capabilities of current hearing aids (with a possible contribution from noise reduction algorithms) have resulted in less negative reactions to amplified environmental sounds. This suggests that modern technology has ameliorated (to some extent) the common complaint that hearing aids cause many everyday sounds to become objectionably loud. Although the results of this study suggest that the advantages of improved technology do not lie in the domains of improved subjective speech communication performance, substantial improvement in the rate of successful adjustment to hearing aids between the 1995 and 2005 subject groups provides evidence that modern hearing aid technology has produced progress in other outcome domains.

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INTRODUCTION

Clinicians and researchers increasingly have recognized the importance of the patient's perspective in evaluating the real-world effectiveness of health interventions, including hearing aids. Indeed, it has been argued that the only valid way to understand, characterize, and quantify the daily struggles of a listener with hearing impairment and then to measure the success or otherwise of a hearing aid fitting in reducing those problems is via structured questioning of each individual. One commonly used method for deriving answers to structured questioning is through the use of self-assessment questionnaires. Self-assessment questionnaires allow clinicians to obtain information about a variety of domains of interest, such as preintervention hearing problems, perceived benefit, residual difficulties, satisfaction, daily use of hearing aids, and health-related quality of life. Modern clinical and research practice has expanded to include the systematic use of self-assessment questionnaires to estimate real-life hearing aid fitting outcomes as a supplement to objective clinical methods. One such questionnaire is the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander 1995).

The APHAB is a standardized self-report inventory that assesses hearing problems in daily life. The 24-item questionnaire is a shortened version of the 66-item Profile of Hearing Aid Benefit (Cox & Rivera 1992). The short version was developed to be suitable for use as part of a clinical hearing aid fitting procedure. It can be used to ". . . document the outcome of a hearing aid fitting, to compare several fittings, or to evaluate the same fitting over time" (Cox & Alexander 1995, p. 176). The original norms for the APHAB were published in 1995 and were determined for patients wearing hearing aids of that era. Since 1995, hearing aid technology has advanced substantially. These improvements in technology prompted the question of whether the 1995 norms were still appropriate to evaluate APHAB scores obtained with modern hearing aids. This study reports an investigation of that question.

The APHAB Questionnaire

In responding to the APHAB items, patients report the frequency of problems they are having with communication or noises in various everyday situations (Cox & Alexander 1995). The questionnaire produces scores for four subscales: ease of communication (EC; strain of communicating under relatively favorable conditions), reverberation (RV; communicating in reverberant rooms), background noise (BN; communicating in noisy environments), and aversiveness (AV; unpleasantness of environmental sounds). Thus, EC, RV, and BN describe speech communication in different listening environments, whereas AV describes negative reactions to environmental sounds. In addition, a Global Score is calculated by averaging the scores for the EC, RV, and BN subscales. The Global Score is used to estimate overall communication problems (e.g., Bleiwess et al. 2001; Hnath-Chisholm & Abrams 2001; Cox et al. 2005).

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A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

Fig. 1. Abbreviated Profile of Hearing Aid Benefit response scale.

Each of the 24 items of the APHAB is a statement. The patient must decide how often the statement is true for his or her daily life. The patient chooses the best response from a list of seven descriptors, each associated with a percentage to help the patient interpret the word (Fig. 1). Example items for each of the four subscales are given below.

1. EC: "When I am having a quiet conversation with a friend, I have difficulty understanding."
2. RV: "When I am talking with someone across a large empty room, I understand the words."
3. BN: "I can communicate with others when we are in a crowd."
4. AV: "The sound of a fire engine siren close by is so loud that I need to cover my ears."

Patients may respond to each questionnaire item for unaided (i.e., "without hearing aids") or aided (i.e., "with hearing aids") listening conditions. The results yield frequency of problems expressed as a percentage. The measured unaided and aided problems may be used directly for evaluation or counseling. In addition, hearing aid benefit may be computed by subtracting the aided problems from the unaided problems (Cox & Alexander 1995). Positive values for aided/unaided differences indicate improvements attributable to the hearing aid. Predictably, difference scores on the AV subscale often are negative after amplification, indicating more frequent difficulty with unpleasantness of environmental sounds when amplification is used.

The APHAB has been used clinically since its development in 1995. *The Hearing Journal*'s 1999 survey of dispensers found that 43% of audiologists reported that they use a formal approach to outcome measurement in their daily practice and that the most popular self-assessment tool was the APHAB (Kirkwood 1999). The APHAB questionnaire and normative data are accessible in NOAH3 hearing aid fitting software (www.himsa.com). Since its introduction, the APHAB has been translated into >15 different languages.

The APHAB also has been used extensively for research purposes. More than 120 English language studies have been published in which researchers have used the APHAB as an assessment tool to measure the appropriateness and patterns of subjective performance for a variety of audiologic interventions. These interventions include hearing aid fitting procedures (e.g., Moore et al. 2005; Gatehouse et al. 2006; Shi et al. 2007) and cochlear implant fitting strategies (e.g., Beynon et al. 2003; Litovsky et al. 2006; Gifford et al. 2007) as well as methods of fitting nonconventional hearing aids such as middle ear implants, partially implantable hearing aids, and bone-anchored hearing aids (e.g., Fraysse et al. 2001; Roland et al. 2001; Hol et al. 2004). The APHAB also has been used to predict hearing aid use (e.g., Freyaldenhoven et al. 2008) and for evaluating relationships between acceptable noise levels and subjective outcome measures for hearing aid and cochlear implant users (e.g., Saxon et al. 2001; Freyaldenhoven et al. 2008; Plyer et al. 2008).

In many clinical and research applications, APHAB scores have been compared with those of the norms for "successful" hearing aid wearers. As noted earlier, the original norms for the APHAB were published in 1995. The data were obtained using a convenience sample of elderly hearing-impaired participants who wore 1990s-era conventional hearing aids. At that time, hearing aids were generally analog or programmable analog, linear processing and peak clipping, single-program devices without noise reduction capabilities. Although directional microphones were available at that time, they were used rarely. Subsequent to 1995, fully digital-processing hearing aids became available and are used widely now. Most digital hearing aids are multichannel wide-dynamic range compression (WDRC) processors. Multichannel systems with WDRC are capable of providing needed amplification to low-level sounds at frequencies where this is needed without overamplifying higher-level inputs. Noise reduction features that aim to improve listening comfort in noise now are routinely included in fittings. In addition, directional microphones that are designed to improve the signal to noise ratio in some listening environments are prescribed much more regularly than they were at the time the original norms were published.

Current hearing aid users typically are fit with hearing aids that implement these features. It is reasonable to postulate that modern technology improvements would result in improved subjective performance for hearing aid wearers. Therefore, it is possible that different norms might be needed for the APHAB to accommodate hearing aid wearers fit with current hearing aid technology. As a result of this possibility, this study was designed to determine whether (1) the responses to the APHAB by users of WDRC-capable hearing devices are significantly different from the responses by users of the more primitive devices worn when the 1995 norms were obtained and (2) APHAB norms derived from scores for users of current hearing aids are different from the original 1995 norms.

PARTICIPANTS AND METHODS

Participants

Potential subjects were identified by private-practice audiologists in seven separate practices. These practices were located in California, Georgia, Louisiana, Michigan, Tennessee, and Texas. They were selected based on their geographical diversity from a list of typical private practices that had offered to participate in the research from this laboratory. Previous research by Cox et al. (2005) indicated that hearing aid patients seen in public hearing-health services show systematic differences in some self-report domains when compared with individuals seen in private-practice services; therefore, public hearing-health clinics (e.g., Veterans Affairs [VA], university clinics, research laboratories) were not included in this study.

This approach to subject recruitment was different from that used to acquire subjects for the 1995 norms. In that study, research subjects were obtained from the Hearing Aid Research Laboratory (HARL) subject data base. Researchers explored file data for those hearing aid wearers who had completed the Profile of Hearing Aid Benefit for one of the several research studies administered by the HARL before 1995. This search resulted in 128 subject records, including subjects who completed the questionnaire either in the laboratory or by mail. In the present study, a more systematic sampling method was used to ensure that subjects were representative of a wide geographic area and widespread clinical practices in hearing aid fitting.

Potential subjects were limited to hearing-impaired individuals aged 60 yrs or older who had been fit bilaterally with hearing aids capable of WDRC processing between 6 and 18 mos before recruitment. Audiologists were asked to identify patients who met these criteria, beginning December 2004 and working backward until they had identified 50 consecutive patients or until June 2003. The audiologists were specifically asked to identify all patients who met the inclusion criteria, regardless of the audiologists' personal judgments about the likely success of the patient in adjusting to the hearing aids. It is worth noting that modern hearing aids often incorporate compression thresholds that are adjustable across a range of levels. Research has not produced convincing evidence to suggest that there is a single optimal approach to configure the parameters of a compression hearing aid. It is typical for the practitioner to begin a fitting with compression programmed according to the manufacturer's protocol, but these settings might be modified during the fine-tuning process. Thus, it is not possible to state whether the hearing aids were fit with the low-compression thresholds that would be necessary to produce compression processing across a wide range of inputs. Nevertheless, all of the hearing aids were capable of WDRC processing, and instruments were fit in a manner consistent with current hearing aid fitting protocols.

Each audiologist mailed the APHAB questionnaire and a cover letter to the addresses of potential participants they had identified. The letter explained the purpose of the research project. Participants who chose to volunteer for the study completed their surveys and mailed them to the first author at the HARL. Participants also were given the opportunity to provide their names and mailing addresses to receive a free packet of hearing aid batteries in the mail in compensation for their effort.

Three hundred and twenty-one surveys were mailed to subjects who met the inclusion criteria, and 154 subjects returned the completed APHAB questionnaires. Table 1 summarizes the distribution of subjects' self-reported age and gender. Sixty-nine participants were men, and 84 were women. These subjects' ages ranged from 50 to 92 yrs,* with a mean age of 74 yrs. Table 2 summarizes the extent of subjects' self-assessed hearing difficulty (unaided). Individuals reported mostly moderate to moderately severe subjective hearing difficulty. Audiogram data were not available in this study.

TABLE 1. Distribution of self-reported age and gender for 154 subjects

Gender	Age: 50–59 yrs	60–69 yrs	70–79 yrs	80–89 yrs	90+ yrs	Did not report	Total
Male	3	10	16	11	1	4	45
Female	2	9	18	18	2	5	54
Did not report	0	0	0	0	0	1	1
Total	5	19	34	29	3	10	100

Data are in percentage.

Hearing Aids

Participants reported the styles of their hearing aids by selecting the appropriate illustration from four choices. Four participants reported use of "open-fit" hearing aids. At the time of data collection, open-fit hearing aids were relatively new, and a representation of an open-fit hearing aid was not provided as a hearing aid style choice. Individuals who reported using open-fit hearing aids chose the behind the ear as most representative of their hearing aid style. Table 2 summarizes the distribution of reported hearing aid styles.

Participants also were asked to document the make and model of their hearing aids. Sixty-one participants were able to provide this information. On the basis of these data, Table 3 summarizes the capabilities of the hearing aids worn by subjects. The majority of individuals who were able to report their hearing aid make and model wore devices with hearing aid capabilities such as directional microphones, digital noise reduction, and multiple programs. Four of those reporting indicated that they wore single-channel hearing aids; 18 wore hearing aids with two to four compression channels; nine wore hearing aids with five to 10 compression channels; and 30 wore hearing aids with >10 compression channels. As noted earlier, although all of the reported hearing aids had compression thresholds capable of being set to <50 dB SPL, we cannot be certain how the compression parameters were adjusted by the audiologists who fit the instruments.

Reported data on daily hearing aid use and duration of experience with amplification were also collected. These data are summarized in Table 4. The majority of subjects had at least 1 yr of hearing aid experience and wore their hearing aids >4 hrs/day.

RESULTS

Comparisons of APHAB Responses for All Subjects

Each subscale of the APHAB comprises six items. To be considered valid, a subscale score must be based on responses to at least four of the six items. From the group of 154 completed questionnaires received, 142 contained valid scores for at least one subscale. These comprised the data used in our analyses. Distribution characteristics of demographic and hearing aid attributes for these subjects were similar to those for all 154 subjects. To assess the similarity of the subject responses from the earlier (1995) study and the current (2005) study, mean data were compared for the two groups for each subscale in unaided and aided listening and for derived benefit. Statistics for each analysis were based on cases with no missing data for any variable in the analysis.

*Although participating audiologists were asked to select potential subjects who were 60 yrs and older, seven individuals who returned questionnaires reported ages ranging from 50 to 58 yrs. These seven individuals were included in the analysis.

TABLE 2. Distribution of reported hearing aid style and subjective unaided hearing difficulty for 154 subjects

	Degree of unaided hearing difficulty						
Hearing aid style	None	Mild	Mod.	Mod.–Sev.	Severe	Did not report	Total
CIC	0	1	6	10	1	1	19
ITC	0	0	6	6	1	0	13
ITE	0	1	5	11	6	0	22
BTE	0	3	9	16	9	1	38
Did not report	1	0	3	1	1	1	7
Total	1	5	29	44	18	2	100

Data are in percentage.
CIC, completely in the canal; ITC, in the canal; ITE, in the ear; BTE, behind the ear (including open-fit behind the ear); Mod., Moderate; Mod.–Sev., Moderately-Severe.

Figure 2 depicts the mean responses for the 1995 and 2005 samples in the unaided listening condition. The average frequency of problems (represented as percentages) is given for both groups for each subscale. The reported frequency of problems without the use of amplification was similar in the two groups for each subscale. Multiple *t* tests were performed to determine whether there were significant differences between groups on any subscale. To avoid inflating the type I error rate with multiple *t* tests, a Bonferroni correction was applied, resulting in an α level of 0.0125 for each test. No significant differences were observed between groups on any subscale. Thus, it is reasonable to conclude that the hearing aid wearers who participated in this study of the APHAB questionnaire were similar to those in the original study in terms of their subjective hearing difficulties in the variety of listening environments encompassed by the content of the questionnaire.

Figure 3 shows the mean responses for the 1995 and 2005 groups in the aided listening condition. The average frequency of problems (represented as percentages) is given for both groups for each subscale. Inspection of the data revealed similar mean responses for the EC, BN, and RV subscales. However, responses for the AV subscale suggested a decrease in reported frequency of problems in this domain for the 2005 sample. The *t* test results supported this observation. Although there were no statistically significant differences between mean responses for EC, BN, and RV subscales, problems of aversiveness were reported less frequently when patients were using WDRC-capable hearing aids ($\bar{X} = 43.3$) than for older hearing aid technology ($\bar{X} = 55$) ($F[1,267] = 13.863$, $p < 0.01$).

Figure 4 presents comparisons of average benefit for the 1995 and 2005 groups. The average benefit score is given for both the groups for each subscale. Predictably, these data reveal similar mean responses for the EC, BN, and RV subscales, whereas comparisons of the AV subscales suggest a decrease in deficit associated with this subscale for the 2005 sample. The *t* test results supported this finding. Comparisons of mean benefit scores indicate nonsignificant differences for the EC, RV, and BN subscales ($p > 0.05$). However, significantly less deficit was noted for the AV subscale for wearers of WDRC-capable hearing aids ($\bar{X} = -20.3$) than for wearers of linear hearing aids ($\bar{X} = -30$) ($F[1,266] = 10.717$, $p < 0.01$).

TABLE 3. Hearing aid capabilities for 61 of 154 subjects

Feature	Capable	Not capable
Directionality	70	30
Noise reduction	74	26
Multiple programs	75	25
Compression thresholds <50 dB SPL	100	0

Data are in percentage.

APHAB Norms for Users of WDRC-Capable Hearing Aids

The APHAB norms are based on percentile scores for successful hearing aid users. For this purpose, "success" is operationally defined as reported daily use of amplification for at least 4 hrs/day and experience with the hearing aid for at least 1 yr. The same procedure was used for the 1995 norms and for the current study. Norms were generated using data from all of the operationally defined successful hearing aid users in the sample. For the 1995 sample, this procedure yielded 55 successful hearing aid users (43% of subjects). For the 2005 sample, 117 subjects were defined as successful (82% of subjects). Distribution characteristics of demographic and hearing aid attributes for the 2005 successful subgroup were similar to those for all subjects in the 2005 sample.

To produce the norms for the unaided listening condition, the score value was determined for the 5th, 20th, 35th, 50th, 65th, 80th, and 95th percentiles of the distribution of scores for each of the four subscales in that listening condition. The same procedure was followed to generate norms for the scores obtained in aided listening and for the computed benefit scores. The results are given numerically in Table 5.

The norms are presented typically and used graphically. When the four subscales are displayed on the same axes, the scores for a given percentile level can be connected by a line, thus producing an equal-percentile profile. In this manner, a family of equal-percentile profiles can be constructed.

TABLE 4. Distribution of hearing aid experience and hours of daily hearing aid use for 154 subjects

	Daily use					
Hearing aid experience	<1 hrs	1–4 hrs	4–8 hrs	8–16 hrs	Did not report	Total
6 wks–11 mos	1	2	2	7	0	12
1–5 yrs	1	4	7	25	0	37
5–10 yrs	0	1	2	19	0	22
>10 yrs	1	1	1	21	0	24
Did not report	1	1	1	1	1	5
Total	4	9	13	73	1	100

Data are in percentage.

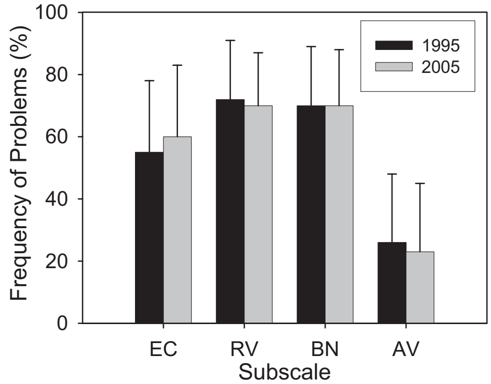

Fig. 2. Mean responses for unaided listening for 1995 ($N = 128$) and 2005 ($N \geq 137$) groups for each subscale. Error bars depict 1 SD. EC, ease of communication; RV, reverberation; BN, background noise; AV, aversiveness.

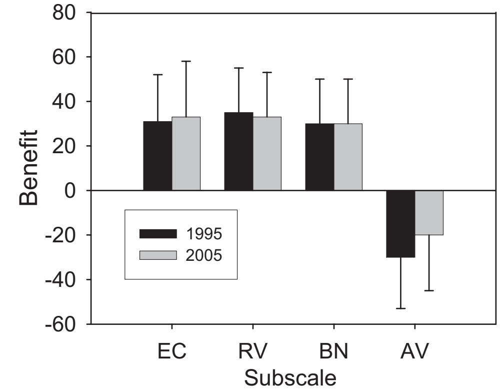

Fig. 4. Mean benefit for 1995 ($N = 128$) and 2005 ($N \geq 136$) subjects for each subscale. Error bars depict 1 SD. EC, ease of communication; RV, reverberation; BN, background noise; AV, aversiveness.

Figure 5 depicts a graphical display of the equal-percentile profiles that comprise the norms for unaided listening. To interpret this graphic, it is useful to remember that 5% of the individuals in the norm group reported less frequent problems than the 5th percentile values, whereas 95% of individuals reported more frequent problems. Similarly, 80% of individuals reported less frequent problems than the 80th percentile values, whereas 20% of individuals reported more frequent problems, and so on.

Looking at subscale scores, equal-percentile profiles provide more information about individuals' listening difficulties when compared with successful hearing aid wearers than examination of raw scores alone. For example, Figure 5 depicts a profile in which an individual reports problems in quiet (EC) about 30% of the time without hearing aids. This individual reports problems in reverberant environments (RV) and in background noises (BN) around 70% of the time without hearing aids and problems with aversion to environmental sounds (AV) approximately 50% of the time. Based on these raw scores, a clinician might not pay much attention to potential problems with loudness of amplified sounds because these problems occur less frequently than difficulties in reverberant and noisy environments. However, by using the norms to compare this patient's scores with those of successful hearing aid wearers, the clinician will realize that the patient is reporting comparatively greater difficulty with environmental sounds than with communication in their daily lives (scores for EC, RV, and BN subscales fall below the 50th percentile, but aversion to environmental sounds is above the 80th percentile). These data suggest that this patient might have difficulty adjusting to amplification as a result of discomfort from amplified sound. Attention to this matter during the initial hearing aid fitting and counseling should improve the likelihood of a successful hearing aid fitting outcome. See Cox (1997) for further discussion of equal-percentile profiles.

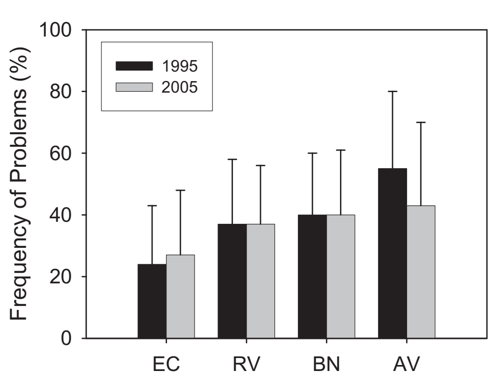

Fig. 3. Mean responses for aided listening for 1995 ($N = 128$) and 2005 ($N \geq 137$) groups for each subscale. Error bars depict 1 SD. EC, ease of communication; RV, reverberation; BN, background noise; AV, aversiveness.

Comparison of 1995 and 2005 Norms

A major motivator for this study was to determine whether the 1995 APHAB norms are valid for patients who are using

TABLE 5. Scores for equal-percentile profiles for APHAB subscale and global scores for successful hearing aid users (defined as daily use of amplification ≥4 hrs/day for 1 yr or more)

		Subscale				
	%ile	EC	RV	BN	AV	Global score
Unaided	95	99	99	99	70	99
	80	83	87	89	35	86
	65	75	81	81	21	79
	50	63	71	75	14	70
	35	56	65	67	9	63
	20	46	58	58	3	54
	5	26	47	41	1	38
Aided	95	86	79	82	82	82
	80	39	57	58	64	51
	65	29	46	49	53	41
	50	23	37	40	38	33
	35	17	29	32	23	26
	20	12	21	22	14	18
	5	5	12	14	2	10
Benefit	95	76	70	56	16	67
	80	52	52	47	0	50
	65	46	41	39	−8	42
	50	38	34	33	−13	35
	35	29	27	23	−25	26
	20	19	16	12	−41	16
	5	−10	−3	−1	−61	−5

Data are given for each response mode.
APHAB, Abbreviated Profile of Hearing Aid Benefit; %ile, percentile; EC, ease of communication; RV, reverberation; BN, background noise; AV, aversiveness.

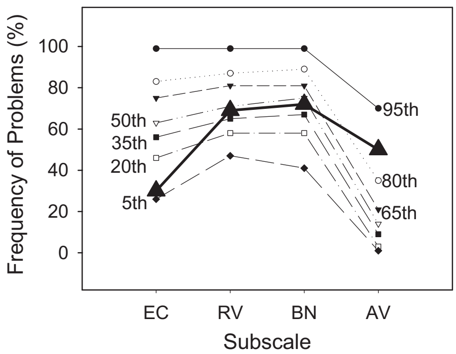

Fig. 5. Equal percentile profiles for the unaided listening condition. Each subscale is represented across the bottom of the figure, and the reported frequencies of problems are represented in percent on the vertical axis. Each profile depicts the subscale scores corresponding to a given percentile in each of the four subscales (e.g., 5% of successful participants reported fewer problems than the 5th percentile for each of the subscales, 5% of successful participants reported more problems than the 95th percentile). The large triangles and solid line represent an unaided Abbreviated Profile of Hearing Aid Benefit profile that might be associated with poor adjustment to amplification resulting from discomfort from amplified sound. EC, ease of communication; RV, reverberation; BN, background noise; AV, aversiveness.

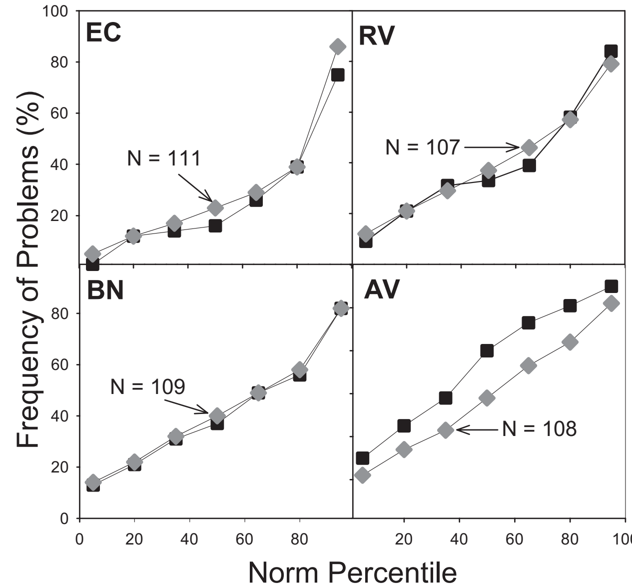

Fig. 7. Comparison of 1995 (squares, $N = 55$) and 2005 (diamonds, N = as shown) norms for the aided listening condition. Data are represented for ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness (AV) subscales.

modern digital hearing aids capable of WDRC processing and with typical digital features, such as directional microphones and noise reduction algorithms. To address this question, the two sets of norms were compared. Figure 6 depicts comparisons of the 5th to 95th percentiles for 1995 and 2005 norms for each subscale in the unaided listening condition. The norms for the EC, BN, and AV subscales seem almost identical. There are small differences in the midpercentile values for the RV subscale with the 1995 group reporting slightly more frequent difficulty with reverberant situations. Overall, the two sets of norms are essentially identical for listening without amplification.

Figure 7 depicts comparisons of the 5th to 95th percentiles for 1995 and 2005 norms for each subscale in the aided listening condition. Differences are minimal for the EC, RV, and BN subscales. However, the 1995 group consistently reported more frequent difficulties with sound aversiveness (AV subscale) than the 2005 group. Depending on the percentile level, hearing aid wearers in the 1990s reported 10 to 20% more frequent problems with aversiveness of amplified sounds than did hearing aids wearers with newer technology in 2005.

Figure 8 depicts comparisons of the 5th to 95th percentiles for 1995 and 2005 norms for each subscale in computed benefit. Norms for the EC subscale are almost identical for the two groups. For the RV and BN subscales, the norms are again only minimally different, although there is some suggestion that the individuals with the most frequent problems in BN (80th and 95th percentiles) reported somewhat less benefit in this listening condition with modern hearing aids. In addition, results for the AV subscale showed that wearers of WDRC-capable hearing aids experienced less deficit resulting from amplification of environmental sounds than did their counterparts in 1995, who were wearing linear-processing devices.

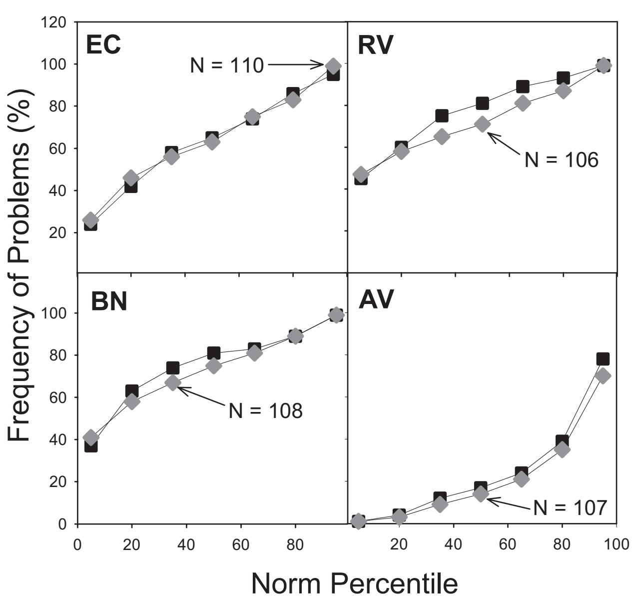

Fig. 6. Comparison of 1995 (squares, $N = 55$) and 2005 (diamonds, N = as shown) norms for the unaided listening condition. Data are represented for ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness (AV) subscales.

DISCUSSION

This study provides a comparison of subjective performance and benefit measured with the APHAB questionnaire for two groups of hearing aid wearers. One group of hearing-impaired individuals wore 1990s-era linear-processing hearing aids, and the other group of hearing-impaired individuals wore 2003 to 2004 WDRC-capable hearing aids. Individuals in the WDRC group were fit using current practice protocols. Thus, the results reflect the real-world effectiveness of WDRC-capable hearing aids because they are used in the current era.

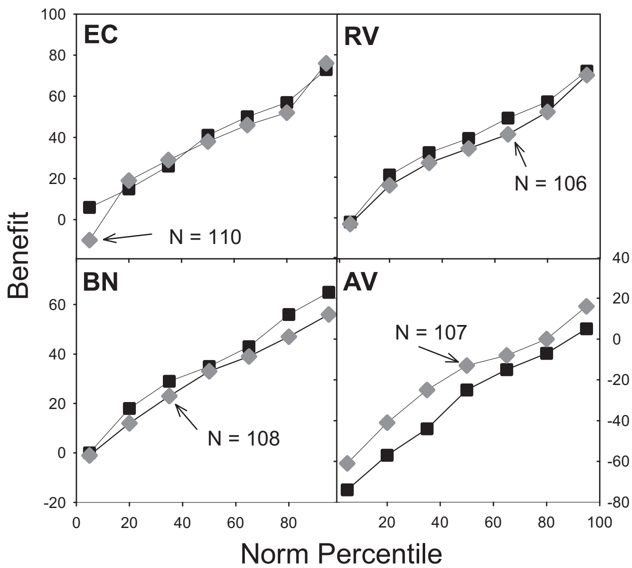

Fig. 8. Comparison of 1995 (squares, $N = 55$) and 2005 (diamonds, $N =$ as shown) norms for derived benefit. Data are represented for ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness (AV) subscales. It should be noted that benefit scores for AV are demarcated on the right axis.

Both groups were assessed in terms of the frequency of problems encountered in daily listening without amplification. The results, illustrated in Figure 2, show that on this measure the two groups were equivalent, indicating that the hearing aid wearers' perceptions of their degree of hearing difficulty without amplification were similar for both groups. These results support the validity of comparing the two groups in aided listening conditions. Any differences in aided listening cannot be attributed to preamplification differences in the degree of hearing difficulty between the 1995 and 2005 subjects.

Although we had hypothesized that improvements in hearing aid technology would have resulted in fewer problems in aided speech communication in daily life, this result was not observed. As illustrated in Figure 3, the aided mean frequency of problems for the EC, RV, and BN subscales was similar for the 1995 and 2005 groups. Overall, this finding implies that problems understanding amplified speech did not decrease in frequency when hearing aids transitioned from linear to compression processing. Although this is a somewhat disappointing outcome, it is consistent with numerous laboratory studies that have shown no overall significant differences in speech recognition between linearly processed speech and speech with WDRC processing (Boike & Souza 2000; Haskell et al. 2002; Shanks et al. 2002). WDRC processing can be expected to yield better speech recognition than linear processing when the speech level is low and listeners do not have access to the hearing aid's volume control (Laurence et al. 1983; Moore et al. 1992; Humes et al. 1999). The importance of this in typical fittings in daily life is not known.

In addition, it was reasonable to anticipate that, with widespread use of WDRC processing and digital noise reduction capabilities, problems with sound AV would be lessened. This is expected because WDRC processing results in more gradual growth of loudness with increasing input, as well as lower maximum output in typical hearing aid fittings and because digital noise reduction algorithms result in reduced hearing aid gain/output in the presence of noisy inputs. Figure 3 shows that problems with AV of amplified sounds (AV scores) did decrease during the 10-yr period between 1995 and 2005. Thus, it can be concluded that the capabilities of current hearing aids have resulted in less negative reactions to environmental sounds when compared with primarily linear hearing aids without digital noise reduction, addressing the common complaint that hearing aids cause many everyday sounds to become objectionably loud (Kochkin 2000; Jenstad et al. 2003). Nevertheless, it should not be assumed that problems with loudness of amplified sounds have been fully solved. There is ample evidence that amplified loud sounds continue to be uncomfortable for many patients on many occasions (e.g., Kochkin 2005; Clutterbuck 2008).

Given that benefit on the APHAB questionnaire is a computed difference between scores for unaided and aided listening, comparisons of mean benefit scores for the 1995 and 2005 groups (Fig. 4) revealed the patterns that would be expected from the data for unaided and aided listening: despite improvements in technology, hearing aids capable of WDRC processing have not resulted in perceived improvements in the magnitude of benefit for speech communication. On the other hand, there have been improvements (reductions) in auditory discomfort with sound amplification.

Most researchers and practitioners seem to believe that modern digital-processing hearing aids offer advantages to hearing aid users that were not available in the early 1990s. The results of this study suggest that those advantages do not lie in the domains of improved subjective speech communication performance (or computed benefit). However, despite the results of this study, it should not be concluded that hearing aid outcomes have not improved during the last decade. It is important to keep in mind that subjective outcomes can be measured in several domains. For example, Cox (2003) described seven separate subjective outcome domains, including daily use of amplification, aided performance, benefit, satisfaction, improved participation, impact on others, and quality of life. Several investigators have shown that these different outcome domains are only moderately related to each other (e.g., Gatehouse 1994; Humes 1999; Humes et al. 2001). Therefore, it is entirely possible that despite a lack of progress in the aided speech communication performance domain, modern hearing aid technology might have produced progress in other outcome domains. In fact, this study provides evidence that this is the case.

As shown in Table 4, data were collected on reported daily hearing aid use. These figures were used to determine which subjects were categorized as having made a successful adjustment to hearing aids (defined as daily use of 4 or more hours during a period of at least 1 yr). These successful subjects were those on whom the norms were based. It was observed that there was a substantial difference in the rate of successful adjustment to hearing aids between the 1995 and 2005 subject groups. In the 1995 group, 43% of the subjects was classified as successful and used for the norms. In the 2005 group, 82% of the subjects was classified as successful and used for the norms. In other words, the proportion of hearing aid wearers who fulfilled the operational definition of success was almost twice as great with modern digital

WDRC-capable instruments as with 1990s-era linear processors. This is an encouraging finding and implies substantial improvement in some types of outcomes as a result of technology improvements over the decade addressed by this study.

Use of New Normative Data

The norms developed in this study reflect the real-world effectiveness of WDRC-capable hearing aids with current technology and fitting practices. The 2005 norms for the APHAB should be used when obtaining baseline (unaided performance) and hearing aid outcome (aided performance) measures for individuals using WDRC-capable hearing aids. This will maximize the likelihood of accurate clinical interpretation of patient responses to the APHAB. These norms were developed just as hearing aid dispensers routinely began to dispense hearing aids with nonoccluding (open) configurations, and only four subjects reported that their hearing aids were open fittings. We cannot be sure whether these norms apply for wearers of open-fit devices. The 2005 and the 1995 norms both are implemented in the most recent versions of the NOAH3 hearing aid fitting software.

As noted earlier, the subjects for this study were limited to audiology private-practice patients. It is appropriate to ask how the derived norms should be viewed and used with public-health patients such as VA patients. Cox et al. (2005) found that typical VA patients provided responses to the APHAB questionnaire that were indicative of slightly better computed benefit outcomes than that seen for typical private-practice patients. Because the differences were small, it would be appropriate for VA audiologists to use the 2005 norms to interpret their patients' APHAB scores. Nevertheless, some caution is advisable, and it should be acknowledged that VA patient outcomes are being compared with norms for private-practice patients.

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