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Speech-Recognition Performance after Long-Term Hearing Aid Use

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Abstract

Larson et al (2000) reported the findings of a multicenter, NIDCD/VA clinical trial that compared hearing aid performance for three output limiting circuits in 360 adults with symmetrical sensorineural hearing loss. The current study was undertaken to examine long-term hearing aid benefit in this same group of participants following five to six years of hearing aid use. The speech-recognition portion of the follow-up study enrolled 108 participants from the original study, 85% of whom were current hearing aid users and 15% of whom had not worn hearing aids during the past month (nonusers). Recognition performance in sound field on the NU-6 (quiet at 62 dB SPL) and the CST (quiet at 74 dB SPL and with -3 and 3 dB signal-to-babble ratios [S/B] at 62 and 74 dB SPL) was measured unaided and aided whenever possible. Speech-recognition abilities decreased significantly since the original study. Speech-recognition decrements were observed regardless of the speech materials (NU-6 and CST), test condition (quiet and noise), S/B (-3 and 3 dB), or stimulus level (62 and 74 dB SPL). Despite decreases in speech recognition, hearing aid benefit remained largely unchanged since the original study; aided performance exceeded unaided performance regardless of presentation level or noise condition. As in the original study, the relations among stimulus level, S/B, and speech-recognition performance were complex.

Key Words: Hearing aids, multitalker babble, speech recognition

Abbreviations: CST = Connected Speech Test; NU-6 = Northwestern University Auditory Test No. 6; S/B = signal-to-babble ratio; rau = rationalized arcsine units

Sumario

Larson y col. (2000) reportaron los hallazgos de un estudio clínicos multicéntrico del NIDCD/VA que comparó el desempeño en el uso de auxiliares auditivos (AA) con tres circuitos de limitación de la salida, en 360 adultos con pérdida auditiva sensorineural simétrica. El estudio actual fue conducido para examinar el beneficio a largo plazo del AA en el mismo grupo de participantes, luego de cinco a seis años de utilización del AA. La porción de reconocimiento de lenguaje del estudio de seguimiento involucró a 108 participantes del estudio original, 85% de los cuáles eran actuales usuarios de AA y 15% que no habían usado AA durante el mes anterior (no usuarios). El desempeño en reconocimiento del lenguaje en campo sonoro con el NU-6 (en silencio a 62

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dB SPL) y con el CST (en silencio a 74 dB SPL, y con tasas de señal/balbuceo de -3 y +3 dB [S&B] a 62 y 74 dB SPL), fue medido con y sin amplificación cuando resultó posible. Las habilidades de reconocimiento del lenguaje habían disminuido significativamente desde el estudio original. Se observó reducción en el reconocimiento del lenguaje independientemente del material logoaudiométrico (NU-6 y CST), las condiciones de la prueba (en silencio o en ruido), S/B (-3 y +3 dB), o la intensidad del estímulo (62 y 74 dB SPL). A pesar de la disminución en el reconocimiento del lenguaje, el beneficio del AA permaneció sin cambios en relación al estudio original; el desempeño con amplificación superó el desempeño sin amplificación sin importar la intensidad de la presentación o las condiciones de ruido. Al igual que en el estudio original, las relaciones entre el nivel de estímulo, la S/B y el desempeño en el reconocimiento de lenguaje fueron complejas.

Palabras Clave: Auxiliares auditivos, balbuceo de hablantes múltiples, reconocimiento de lenguaje

Abreviaturas: CST = Prueba de Lenguaje Conectado; NU-6 = Prueba Auditiva No. 6 de la Universidad Northwestern; S/B = tasa señal/balbuceo; rau = unidas racionalizadas de arcoseno

The original NIDCD/VA hearing aid clinical trial initiated in 1996 compared performances of 360 adults with symmetrical sensorineural hearing loss using three different output limiting circuits (peak clipping, compression limiting, and wide dynamic range compression) (Larson et al, 2000). Three categories of outcome measures (speech recognition, sound quality, and subjective ratings) were used to measure hearing aid benefit following a three-month trial with each circuit. All subjects were allowed to keep the hearing aids, which were programmed to their preferred circuit, at the termination of the study. The current study was undertaken to examine long-term hearing aid benefit in this same group of participants following five to six years of hearing aid use. Background information on both the original and follow-up studies and specifics on the hearing aid circuits can be found in the first two articles in this issue by Bratt et al and Peek et al. Tables 1 and 2 in the Bratt et al article list the control and outcome measures administered to the 210 participants available for the follow-up study. The number of participants completing each of the measures varied depending on whether participation was completed by phone survey, home visit, or clinic visit. This article focuses on the speech-recognition outcome measures following long-term hearing aid use in a subgroup of participants who were evaluated during a clinic visit.

The original NIDCD/VA hearing aid clinical trial investigated hearing aid benefit for the three output limiting circuits using two speech-recognition outcome measures (Shanks et al, 2002). The Northwestern University Auditory Test No. 6 (NU-6; Tillman and Carhart, 1966) was used to evaluate unaided and aided word-recognition performance in quiet at 62 dB SPL. The Connected Speech Test (CST; Cox et al, 1987; Cox et al, 1988) was used to evaluate unaided and aided speech-recognition abilities in a background of multitalker babble in the following ten listening conditions: three signal-to-babble ratios (S/B) at three speech levels (soft speech at 52 dB SPL, conversational speech at 62 dB SPL, and loud speech at 74 dB SPL) and in quiet at 74 dB SPL. The decision was made in the original study to equate subjects by performance level rather than by babble level. The reference S/B was defined as the babble level that resulted in 50% performance on the CST presented at 62 dB SPL. The other two S/B were -3 dB and 3 dB with respect to this reference condition.

Several results from the original study were noteworthy (Shanks et al, 2002). Although differences in speech-recognition performance among the three circuits were minimal, significant hearing aid benefit (defined as aided minus unaided performance) was demonstrated for both the NU-6 in quiet and the CST in quiet and in multitalker babble. As expected, benefit was greatest for speech presented at low levels and smallest for speech presented at high

levels. In addition, several interesting relations were noted for the CST in background noise. Specifically, unaided performance on the CST revealed a complex relationship between presentation level and S/B that was confounded by the degree of hearing loss. As speech level increased from 52 to 74 dB SPL, listeners with mild hearing loss showed a decrease in speech-recognition performance whereas listeners with moderate hearing loss showed an increase in performance.

The lengthy protocols used in original study were abbreviated in the follow-up study to include the NU-6 in quiet (aided and unaided) and the CST in five of the ten conditions used in the original study. This report focuses on the following aspects of the follow-up study: (1) to compare unaided versus aided speech-recognition performance after five to six years of hearing aid use, (2) to compare hearing aid benefit between the original and follow-up studies, and (3) to compare word-recognition performance for participants who continued to use hearing aids versus those who stopped using hearing aids.

METHODS

Participants

One hundred eight of the original 332 participants from eight Veterans Affairs Medical Centers completed the speech-recognition portion of the follow-up study. Seventy-six percent of the participants in the follow-up study were veterans in contrast to 70% in the original study. The remainder of the subjects was recruited from the private sector in order to make results applicable to a broad range of hearing aid users. Participants were paid $150 to complete the four-hour protocol described by Bratt et al (in this issue). Participants aged an average of six years from 67.2 years in the original study to 73.2 years in the current study. Variations in sample size across tests and conditions reflect missing data due to factors such as unavailable or malfunctioning hearing aids and inability of a participant to complete a task.

Pure-tone thresholds and word recognition on the CID W-22 (Hirsh et al, 1952) were tested prior to administration of the two speech outcome measures. W-22 word-recognition performance, measured in quiet at a minimum of 80 dB HL and averaged across the two ears for this subgroup of participants, decreased from 87% in the original study to 75% in the follow-up study. Hearing sensitivity also decreased over the six-year period between studies. The top panel of Figure 1 compares mean pure-tone thresholds for the same 108 participants in the original (squares) and follow-up (diamonds) studies; standard deviations are shown in parentheses. On average, hearing sensitivity decreased by 5 to 12 dB across the entire frequency range since the first

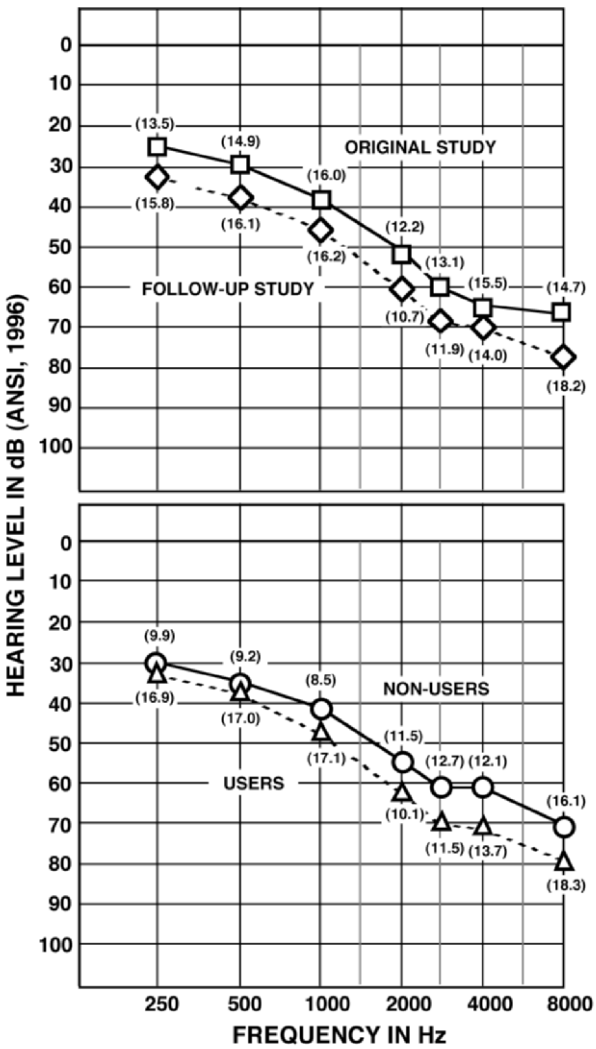

Figure 1. Comparison of pure-tone air-conduction thresholds for the 108 participants in the original (squares) versus follow-up (diamonds) studies in the top panel and for current hearing aid users (triangles, n = 92) versus non–hearing aid users (circles, n = 16) in the bottom panel; standard deviations are shown in parentheses.

study. In addition, 79% of the participants showed a decrease in the three-frequency pure-tone average of ≥5 dB relative to the original study.

Pure-tone thresholds also were compared for current hearing aid users versus nonusers. Approximately 15% of the 108 participants, who reported that they had not worn hearing aids during the one-month period prior to data collection, were classified as nonusers. This nonuse rate is in general agreement with the Kochkin (2001) survey that reported an 11.7% nonuse or "in-the-drawer" rate for hearing aids four years old or newer. As depicted in Figure 1, pure-tone thresholds for nonusers (circles) were on average 6–10 dB better than users (triangles) in the 1000–8000 Hz range. Six of the 16 nonusers had functioning hearing aids and were tested in both the aided and unaided portions of the study. The remaining participants were tested only in the unaided conditions.

The preceding article by Peek et al (in this issue) describes the hearing aids and settings used by the participants in the follow-up study. Fifty-one percent of current hearing aid users in the 418-A cohort were wearing original study aids, and 78% of these aids were still set to the circuit programmed at the end of the original study. Although all hearing aids were tested electroacoustically to verify proper functioning, the hearing aids were not reprogrammed to target. Because the purpose of the follow-up study was to determine how the original cohort of participants functioned with their current hearing aids, the speech measures were performed using their current hearing aids set at use gain. The preferred-use gain for each participant was determined while listening to a practice passage of the CST presented at 62 dB SPL in the sound field at 0° azimuth at a distance of 1.4 m. Participants were instructed to listen to the passage and adjust their hearing aids to a comfortable loudness level. Peek et al (in this issue) reported that real-ear insertion gain from 500 to 2000 Hz measured at preferred-use gain was an average of 6–7 dB below current target real-ear insertion gain calculated to NAL-RP and based on current hearing loss. This difference between use and target gain is similar to that reported by Humes et al (2002) and may reflect user preference for less gain than is prescribed.

Procedures

Aided and unaided speech recognition was evaluated in the sound field. Aided performance was measured for all participants with functioning hearing aids, even if they were classified as nonusers. Speech materials were delivered from a custom compact disc via a personal computer. The computer output was amplified and routed to a loudspeaker placed at 0° azimuth and 1.4 m from the participant. Uncorrelated multitalker babble was presented from loudspeakers positioned 1 m from the participant at 45° to the left and right of center. The calibration of both the speech and babble levels was verified prior to each test session with the microphone of the sound-level meter (Larson-Davis, Model 800B) positioned to simulate the head position during testing.

Two speech-recognition tests, chosen to represent a range of linguistic complexity, were used in the current study. The NU-6 word lists (Tillman and Carhart, 1966) were selected because the test items have limited linguistic information. In contrast, the CST was selected because these sentence materials provide both semantic and syntactic information. NU-6 words were presented to 108 participants in the unaided condition and 95 participants in the aided condition. A 50-word list was administered in quiet at 62 dB SPL under both aided and unaided conditions. The audio compact disc version of the NU-6 lists used in this study was recorded by a female talker (*Speech Recognition and Identification Materials, Disc 2.0* [Department of Veterans Affairs, 1998]). The aided condition was tested first, followed by the unaided condition. For the aided presentation, the hearing aids were set to use gain. The verbal responses of the participants were logged and scored.

The CST was presented to 107 participants in the unaided condition and 91 participants in the aided condition. The CST, spoken by a female, consisted of 48 test passages and 9 practice passages, each with eight to ten meaningfully related sentences. The 48 passages were paired to produce 24 test passages with 50 target words. The CST was administered in five listening conditions: two presentation levels (loud speech at 74 dB SPL and conversational speech at 62 dB SPL), two S/B (-3 and 3 dB),

and in quiet at 74 dB SPL. The five CST conditions are specified by presentation level and babble level as follows: 74/-3, 74/3, 62/-3, 62/3, and 74/Q. Verbal responses of the participants were logged and scored.

The S/Bs established for each participant in the original study (Shanks et al, 2002) also were used for the follow-up study. Recall that participants in the original study were equated by performance level rather than by babble level. The reference S/B was defined as the babble level that produced 50% performance on the CST presented at 62 dB SPL. The binaural babble levels, therefore, varied across participants and ranged from 42 to 71 dB SPL with a mean and standard deviation of 58 and 5.6 dB, respectively. Eighty-four percent of the babble levels ranged from 50–64 dB SPL and, as expected, tended to be lower in participants with the greatest hearing loss (see Table 1 in Shanks et al, 2002).

The following order for CST testing was designed to match the original study: aided at 74 dB SPL in quiet (74/Q), aided at 74 dB SPL with S/B of -3 and 3 dB (74/-3 and 74/3), and aided at 62 dB SPL with S/B of -3 and 3 dB (62/-3 and 62/3). The same test order was followed for the five unaided conditions. Prior to administering each test condition, the participants listened to a practice passage, during which they were allowed to adjust their hearing aids as they normally would under noisy listening conditions. The presentation in quiet was performed at use gain. The participants then were given a laminated card listing the sentence topics for the CST. Participants were instructed to repeat the entire sentence exactly as it was heard. The stimuli were paused between sentences to allow participants ample time to respond. When the aided conditions were completed, the participants were instructed to remove their hearing aids, and the unaided testing was completed.

Statistical Analysis

Speech-recognition scores in percent correct were converted to rationalized arcsine units (rau) prior to statistical analyses (Studebaker, 1985). As in the original CSP-418 study, this transformation was used to minimize the relationship between the variance and the mean. The transformation results in a scale that is linear rather than asymptotic near the two performance extremes of 0 and 100%. Performance scores reported in percent and rau are nearly equivalent between 15 and 85% and vary considerably at the two extremes of the function with scores in rau ranging from greater than 100 to less than 0. All statistical analyses and graphs are in rau; for purposes of comparison, tabled data are presented in percent correct.

Comparisons based on current hearing aid usage ("yes" versus "no") were conducted using two-sample t-tests for independent groups. Paired t-tests were employed to compare the aided and unaided scores as well as the scores from the original and follow-up studies. Each comparison was considered statistically significant for p values $\leq .05$.

RESULTS AND DISCUSSION

NU-6

Table 1 shows the mean aided and unaided performances on the NU-6 in percent correct for both the original and follow-

Table 1. Mean Performance in Percent Correct on the NU-6 for Both the Follow-up and Original Studies

Condition	N	Mean	SD	Minimum	Maximum
Follow-Up					
Aided	95	71.4*	18.8	18	98
Unaided	108	40.2	29.3	0	92
Original					
Aided	102	82.5*	12.7	36	100
Unaided	97	51.9	27.6	0	94

Note: Significant differences between aided and unaided performance in the two studies are designated with an asterisk.

*Significant ($p < .001$)

up studies. All comparisons to the original study were based on the same group of participants. As shown in Table 2, the number of participants performing each condition varied depending on availability of functioning hearing aids and ability to complete a task. Figure 2 displays the mean unaided and aided performance (in rau) and the hearing aid benefit on the NU-6 presented in quiet at 62 dB SPL for both the original (shaded bars) and follow-up (striped bars) studies. Three findings are apparent from this figure. First, aided performance significantly ($p < .001$) exceeded unaided performance on the NU-6 test. The average performance in the current study improved from 37 rau for the unaided condition to 72 rau for the aided condition. This finding is consistent with the original study in which this same group of participants showed significant ($p < .001$) improvement in performance from 50 to 86 rau for the unaided and aided conditions, respectively.

Second, both unaided and aided performance decreased significantly ($p < .001$) between the original and follow-up studies. Relative to the original study, mean performance for the unaided and aided conditions in the follow-up study decreased by an average of 12 rau and 8 rau, respectively. The decrease in overall performance is probably due to the combined effects of decreased hearing and differences in hearing aid gain settings between the original and follow-up studies. Recall that hearing sensitivity decreased by an average of 8 dB across all frequencies since the original study and that preferred-use gain in the current study was an average of 6–7 dB below target (Peek et al, in this issue).

Third, although both aided and unaided performance on the NU-6 decreased significantly in comparison with the first study, the mean hearing aid benefit, calculated as aided minus unaided performance, remained unchanged. Average hearing aid benefit in the current study was 37 rau compared with 36 rau for this same group of participants from the original study. Individual hearing aid benefit in both studies, however, varied widely, ranging from -6 to 94 rau in the current study and from 0 to 108 rau in the original study.

Figure 3 shows a comparison between

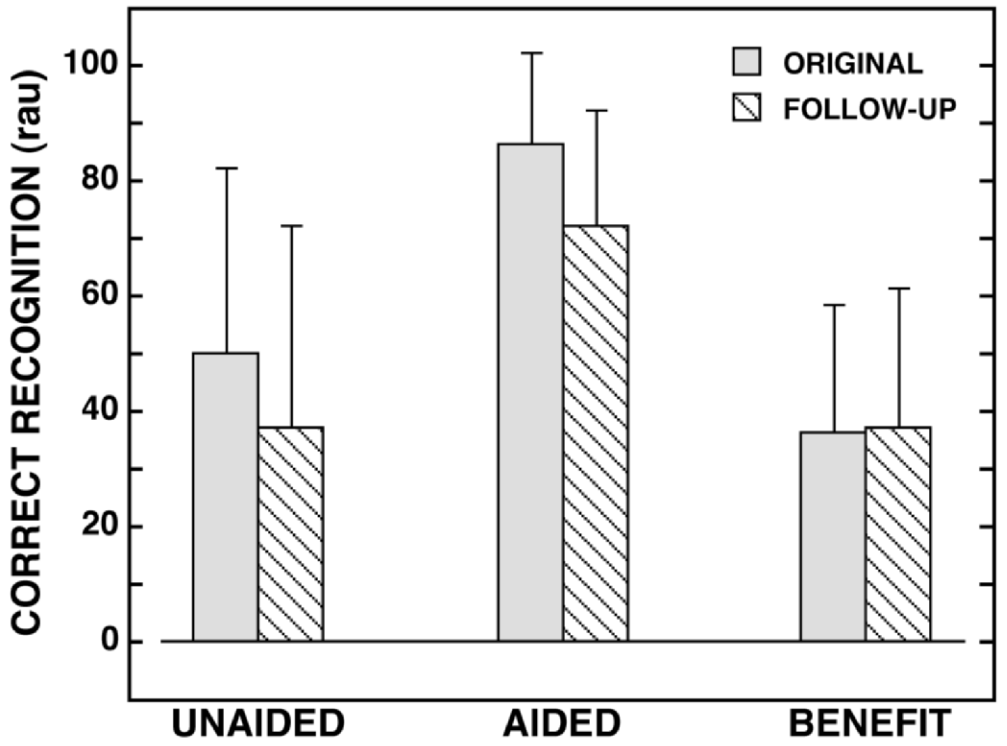

Figure 2. Mean unaided and aided performance (in rau) and hearing aid benefit, calculated as aided minus unaided performance, on the NU-6 presented in quiet at 62 dB SPL for both the original (shaded bars) and follow-up (striped bars) studies. The brackets indicate one standard deviation.

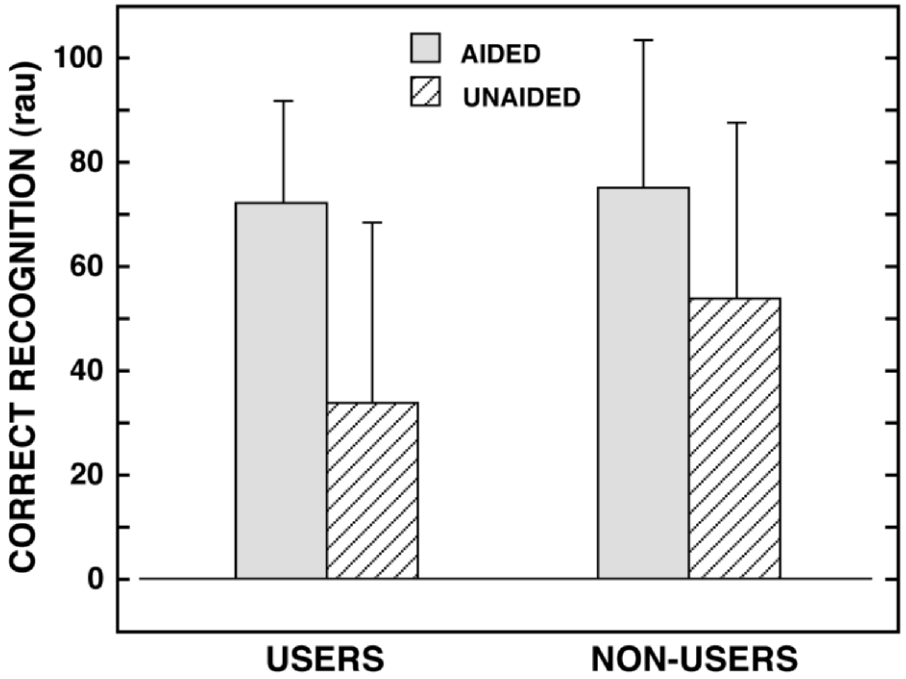

Figure 3. Aided (shaded bars) and unaided (striped bars) performance (in rau) on the NU-6 presented in quiet at 62 dB SPL for current hearing aid users versus nonusers in the follow-up study. Six nonusers were tested in the aided condition, and 16 nonusers were tested in the unaided condition. The brackets indicate one standard deviation.

Table 2. Mean Performance in Percent Correct on the CST for Both the Follow-Up and Original Studies

Condition	N	Mean	SD	Minimum	Maximum
Follow-Up					
Aided					
74/Q	91	86.5*	15.0	4	100
74/-3	91	38.5*	27.6	0	96
74/3	91	63.0**	22.9	0	100
62/-3	90	43.5*	26.2	0	94
62/3	90	70.0*	20.8	0	96
Unaided					
74/Q	107	73.7	26.4	0	100
74/-3	107	32.9	24.4	0	90
74/3	107	57.6	25.5	0	98
62/-3	106	27.0	22.4	0	84
62/3	106	42.5	27.8	0	96
Original					
Aided					
74/Q	108	92.7*	9.6	44	100
74/-3	107	37.5*	27.1	0	98
74/3	107	74.5*	17.3	22	100
62/-3	107	48.8*	26.0	2	96
62/3	107	79.2*	14.2	28	100
Unaided					
74/Q	107	84.1	19.6	0	100
74/-3	104	30.8	21.8	2	90
74/3	104	65.8	17.4	12	98
62/-3	99	31.2	19.2	0	84
62/3	99	59.2	20.8	2	100

Note: Significant differences between aided and unaided performance in the two studies are designated with an asterisk.

*Significant ($p < .001$) **Significant ($p = .025$)

aided and unaided performance on the NU-6 test presented in quiet at 62 dB SPL for current hearing aid users (n = 92) versus nonusers (n = 16) who had not worn hearing aids during the past month. Statistical analysis showed no difference in aided performance between users and nonusers. This statistical comparison, however, was limited because only 6 of the 16 nonusers had functioning hearing aids allowing them to be tested in the aided condition. Interestingly, a comparison of unaided performance for the two groups revealed that nonusers performed significantly better than users by an average of 20 rau (p = .0304). Recall that the nonusers also had better hearing than the hearing aid users. Hearing aid users showed an average hearing aid benefit of 38 rau, whereas nonusers showed an average benefit of only 21 rau.

CST

Table 2 shows mean aided and unaided performance on the CST in percent correct for both the original and follow-up studies. As with the NU-6 data, all comparisons to the original study were conducted on the same participants; variations in sample size across conditions again reflect missing data.

The mean CST performances (in rau) on the five aided and unaided conditions are shown in Figure 4. The top panel depicts the CST results from the original study, and the bottom panel shows the results for the same group of participants (n = 91 aided and n = 107 unaided) from the follow-up study. Three findings are evident from this figure. First, as was demonstrated with NU-6 results in quiet, the mean aided performance (filled squares) on the CST exceeded unaided performance (open squares) for all five listening conditions. For this subpopulation from the original study, aided performance was significantly ($p < 0.001$) better than unaided performance in all five conditions. In the current study, aided performance again was significantly better than unaided performance ($p < 0.001$) for all conditions except 74/3 ($p = 0.025$). Both the original and the follow-up studies demonstrated that hearing aids provided significant benefit in quiet and in background noise.

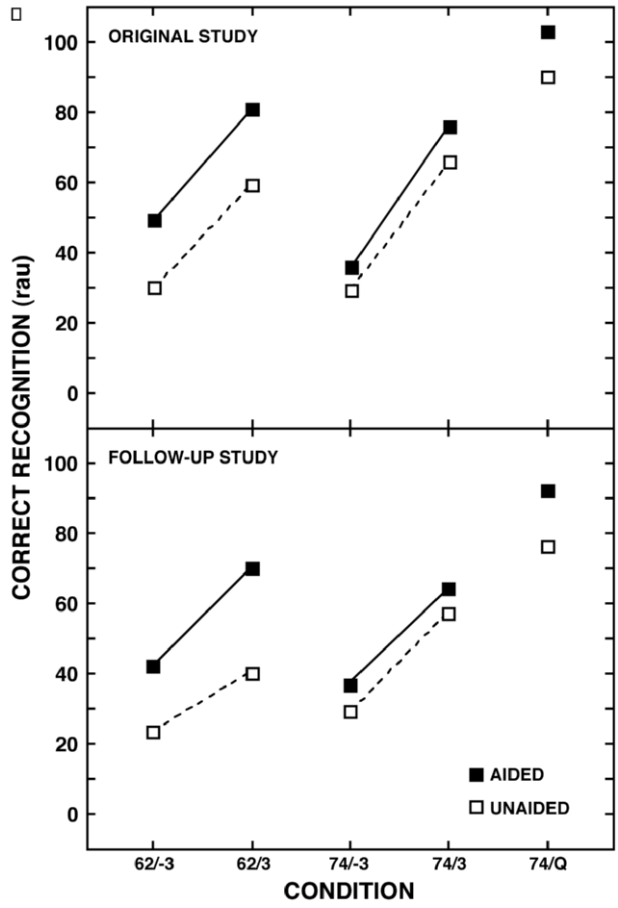

Figure 4. Mean CST performance (in rau) in the original study (top panel) compared with the follow-up study (bottom panel) for the five aided (filled squares) and unaided (open squares) test conditions. The five CST conditions are designated by presentation level (62 or 74 dB SPL) followed by S/B level (-3 or 3 dB S/B and in quiet).

Second, as anticipated, performance on the CST, both with and without hearing aids, was better in quiet (74/Q) than in noise. The mean performance in quiet was 76 rau unaided and 92 rau aided. In the presence of multitalker babble, the maximum unaided performance was 57 rau, and the maximum aided performance was 70 rau. In fact, *unaided* performance of 76 rau in quiet exceeded the average *aided* performance for all four noise conditions. These reports support the common claim from patients that speech recognition is adversely affected by background noise.

Third, as was observed for the NU-6 results, overall performance on the CST

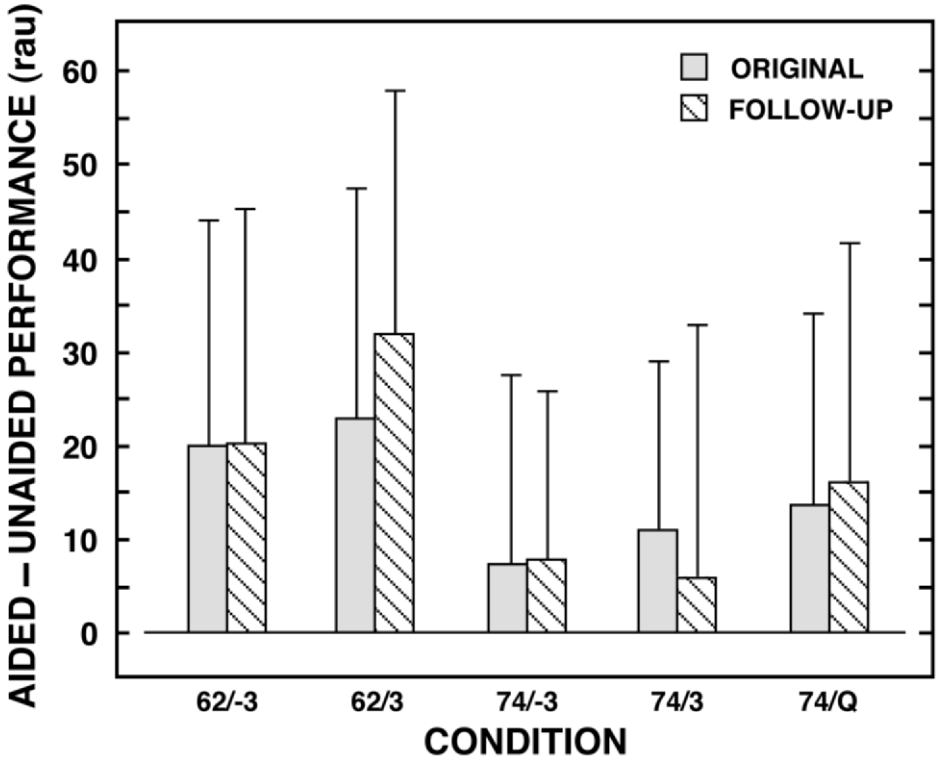

Figure 5. Mean hearing aid benefit (in rau) for the five test conditions of the CST in both the original study (shaded bars) and the follow-up study (striped bars). The brackets indicate one standard deviation.

was poorer in the follow-up study than in the original study. Of the ten conditions plotted in Figure 4, seven conditions resulted in significantly poorer performance in the follow-up study. The exceptions occurred for three of the four -3 dB S/B conditions (unaided at 62/-3 and both aided and unaided at 74/-3). The greatest decreases in performance over the past five years occurred in quiet and for the 3 dB S/B conditions, resulting in more gradual slopes for the functions in the bottom panel in comparison with the functions in the top panel. In other words, mean performance decreased only slightly (0–7 rau) for the less favorable -3 dB S/B listening condition but decreased by 6–16 rau for the more favorable 3 dB S/B listening conditions and in quiet. Recognition performance on the easier listening conditions became more difficult over the past five to six years.

In Figure 5, the data from Figure 4 are replotted to reflect hearing aid benefit (aided-unaided performance). Hearing aid benefit in both studies is greater for the lower presentation level of 62 dB SPL in comparison with 74 dB SPL. As expected, hearing aids are more beneficial for soft speech in which audibility is an issue than for loud speech in which audibility is less often a factor. Hearing aid benefit in the follow-up study was the largest (32 rau) for the 62/3 condition and smallest (6–8 rau) for the two 74 dB SPL conditions. Although aided performance was significantly better ($p < .05$) than unaided performance, individual analysis of the two 74 dB SPL conditions showed that 38 of 91 individuals (42%) performed poorer aided than unaided for the 3 dB S/B condition, and 22 of 91 (24%) performed poorer aided than unaided for the -3 dB S/B condition.

Figures 4 and 5 illustrate that hearing aid benefit varies both with presentation level and S/B. In the original study, a complex interaction was demonstrated among signal level, babble level, and degree of hearing loss. Aided performance on the CST decreased at the higher presentation level even though the ratio was held constant. In the original study, a decrease in performance was observed both in the unaided conditions for participants with the least amount of hearing loss and in all participants in the aided conditions. The data in Figure 6 illustrate these interactions for

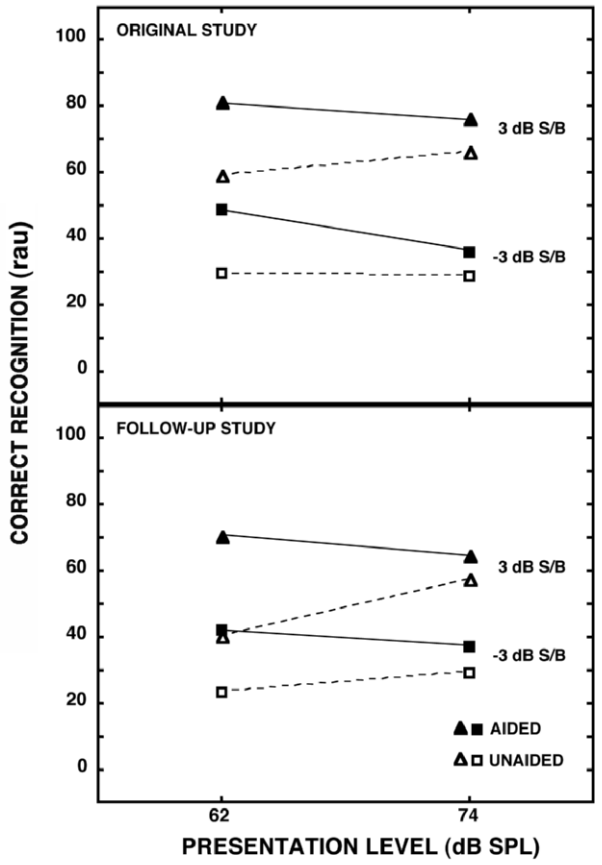

Figure 6. Mean CST performance (in rau) for the two presentation levels as a function of the S/B. The open symbols connected with the dashed lines depict unaided performance, and the filled symbols connected with solid lines depict aided performance for the 3 dB S/B (triangles) and -3 dB S/B (squares) conditions. The top panel displays results from the original study, and the bottom panel shows results for the same group of participants from the follow-up study.

the original study (top panel) and for the same participants in the follow-up study (bottom panel). Because of the reduced number of participants in the follow-up study, the participants were not divided by degree of hearing loss as in the first study. In the follow-up study, unaided performance (open symbols with dashed lines) increased with presentation level by 17 and 6 rau at the 3 and -3 dB S/B, respectively. In contrast, aided performance (filled symbols) *decreased* by 5 to 6 rau at the two S/Bs as signal level *increased*. A similar pattern was noted in the original study (top panel). The increased slope for the unaided functions in the follow-up study probably reflects decreased audibility over the past five to six years. Although aided performance for the -3 dB S/B decreased by an average of 5 rau as level increased to 74 dB SPL in the current study, the effect was not as marked as the 13 rau decrease in aided performance measured in the original study.

Finally in Figure 7, performance on the CST was compared for current hearing aid users (shaded bars) versus nonusers (filled bars). Recall that 16 of the 108 participants were classified as nonusers with only 6 of those tested in the aided condition. As was found with the NU-6 test, the mean unaided performance (right half of the figure) was better for nonusers than for hearing aid users. In contrast, mean aided performance (left half) was higher for users than for the nonusers. None of the differences, however, were significant for this small subject sample.

SUMMARY AND CONCLUSIONS

Over the five to six intervening years between the original NIDCD/VA study and the follow-up study, participants experienced significant decreases both in hearing sensitivity and in word-recognition abilities. Hearing decreased by an average of 8 dB across the frequency range (250–8000 Hz). Speech-recognition decrements were observed regardless of the speech materials (NU-6 vs. CST), test condition (quiet vs. noise), S/B (-3 or 3 dB), or stimulus level (62 or 74 dB SPL). Decrements in word-recognition performance, however, were greater for the easier listening conditions (i.e., quiet and 3 dB S/B) than for the less favorable listening condition (i.e., -3 dB S/B). Unaided W-22 performance in quiet decreased by an average of 12%, and aided NU-6 performance in quiet decreased by an average of 11%. Aided CST performance in quiet and for the 3 dB S/B conditions decreased by 7–12% in comparison with changes of only 1–6% for the less favorable, -3 dB S/B, conditions. Decrements in speech recognition probably are due to the combined effects of decreased hearing, lower hearing aid gain, and reduced cognition associated with aging (Gordon-Salant and Fitzgibbons, 1997, 2005; Hallgren et al, 2001; Humes and Floyd, 2005).

Despite these decreases in speech recognition, the relative benefit from hearing aids remained unchanged since the original study. That is, aided performance exceeded

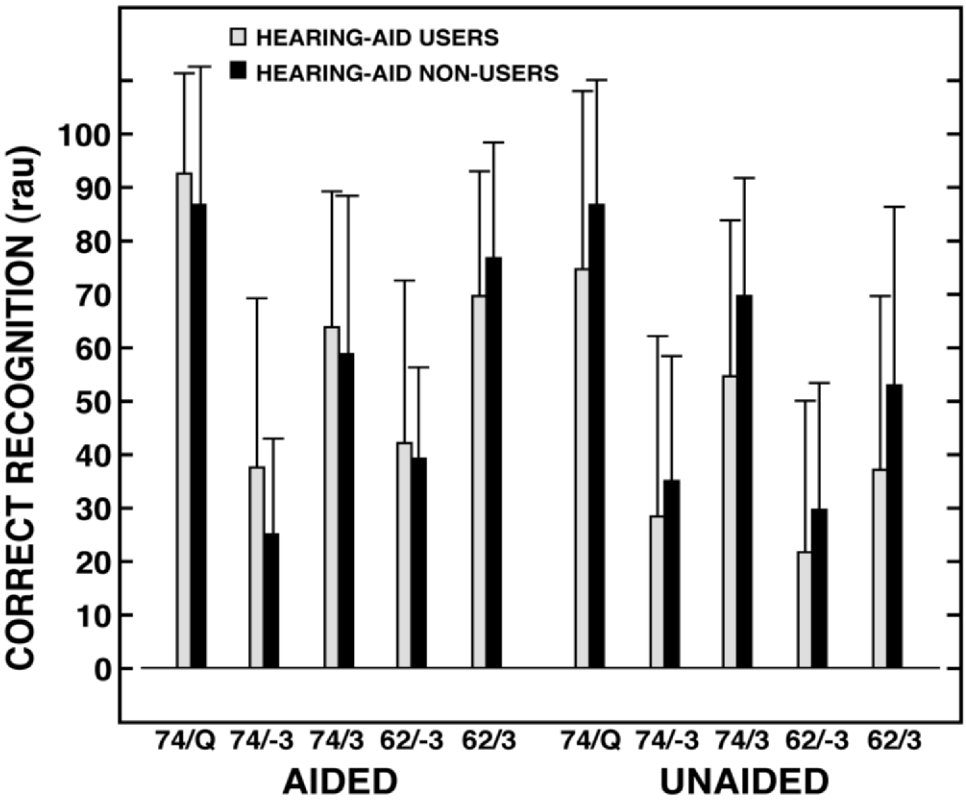

Figure 7. Mean performance (in rau) on the CST for current hearing aid users (shaded bars) versus nonusers (filled bars).

unaided performance regardless of stimulus level or noise condition. As expected, hearing aid benefit was greater for conversational speech than for loud speech. Interestingly, the relation between stimulus level, S/B, and performance was complex. At both 3 and -3 dB S/B in the unaided condition, an increase in stimulus level improved performance. In the aided condition, however, an increase in stimulus level resulted in a decrease in performance (see Figure 6). These findings are consistent with previous reports that a better S/B is needed at high stimulus levels than at low levels in order to achieve equivalent performance (Studebaker et al, 1999; Hornsby and Ricketts, 2001; Shanks et al, 2002).

In the unaided condition, word recognition in quiet exceeded performance in all four of the aided conditions in noise. These results confirm patient complaints regarding the deleterious effects of background noise and support the use of advanced technology (e.g., directional microphones, single microphone noise reduction) to improve listening in noise. In a willingness-to-pay study of veterans fit with hearing aids, Chisolm and Abrams (2001) found that minimizing the effects of background noise was the most valued hearing aid benefit.

Finally, 85% of the participants in the word-recognition portion of the follow-up study were current hearing aid users. The remaining 15%, who were classified as nonusers, demonstrated better hearing and better word recognition in the unaided condition than the users. Indeed, Takahashi et al (in this issue) report that nonusers also *perceived* less difficulty in unaided listening situations than current hearing aid users.

In summary, a somewhat amazing finding of this study is that, despite a decrease in hearing sensitivity since the original study and the fact that use gain was suboptimal relative to target values, this group of patients demonstrated hearing aid benefit that was similar to that measured in the original study. In addition, the hearing aid use rate of 85% indicates a high level of acceptance of hearing aids by the participants in this study.

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