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Clinical Implications of Word Recognition Differences in Earphone and Aided Conditions

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Objective: To compare word recognition scores for adults with hearing loss measured using earphones and in the sound field without and with hearing aids (HA).
Study Design: Independent review of presurgical audiological data from an active middle ear implant (MEI) FDA clinical trial.
Setting: Multicenter prospective FDA clinical trial.
Patients: Ninety-four adult HA users.
Interventions/Main Outcomes Measured: Preoperative earphone, aided word recognition scores, and speech intelligibility index.
Results: We performed an independent review of presurgical audiological data from an MEI FDA trial and compared unaided and aided word recognition scores with participants' HAs fit according to the NAL-R algorithm. For 52 participants (55.3%), differences in scores between earphone and aided conditions were >10%; for 33 participants (35.1%), earphone scores were higher by 10% or more than aided scores. These participants had significantly higher pure-tone thresholds at 250, 500, and 1000 Hz, higher pure-tone averages, higher speech recognition thresholds (and higher earphone speech levels [$p = 0.002$]). No significant correlation was observed between word recognition scores measured with earphones and with hearing aids ($r = 0.14$; $p = 0.16$), whereas a moderately high positive correlation was observed between unaided and aided word recognition ($r = 0.68$; $p < 0.001$).
Conclusion: Results of these analyses do not support the common clinical practice of using word recognition scores measured with earphones to predict aided word recognition or hearing aid benefit. Rather, these results provide evidence supporting the measurement of aided word recognition in patients who are considering hearing aids.
Key Words: Hearing—Hearing aids—Hearing loss—Sensorineural hearing loss—Word recognition.

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Sensorineural hearing loss affects 35% to 42% of individuals ≥65 years of age, making it the most common sensory deficit and one of the most common disabilities in the United States (1,2). Hearing loss not only affects the ability to communicate, but also impacts patients' social, behavioral, and cognitive function, which can lead to social isolation and depression (3–8). Hearing aids are the standard treatment for older adults with mild to severe sensorineural hearing loss.

In contrast to standardized measurement of speech recognition threshold (SRT), there is no universally accepted standard method for measuring suprathreshold word recognition (9). Studies have shown that word recognition scores can greatly vary both within individuals and among populations based on patterns of hearing loss and speech levels (10). It has been suggested that maximum speech recognition scores can be identified using a range of speech levels (11–14). However, use of multiple levels for measurement of speech recognition is not common in the clinical setting (15), where the most common practice is to present a list of monosyllabic words in quiet to each ear through earphones, with speech presented at one relatively high level (e.g., 30–40 dB SL re: SRT).

Results from the standard audiologic test battery have a major impact on numerous decisions made in otologic clinics and for patient recommendations. Specifically, clinicians who see individuals with hearing loss use information from word recognition scores measured with earphones as a general marker to advise patients how they are expected to perform with hearing aids, despite the lack of evidence of their predictive value for aided word recognition. The general assumption is that patients'

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word recognition measured for each ear with earphones in a sound-treated room will be similar to their word recognition with hearing aids in the sound field. Similarly, clinical decisions, such as a patient's use of hearing aids versus a cochlear implant, are based on word recognition measures using earphones.

Clinicians may rely on word recognition scores measured with earphones from the standard audiologic battery because it is often the only information available for decision making at the time of the patient's visit. Unfortunately, peer-reviewed evidence to support this common clinical practice is not available. That is, direct comparisons of word recognition by individuals with hearing loss measured with earphones and measured without and with hearing aids is lacking. Thus, it was of interest to assess these associations for a large sample of adults with a range of hearing loss to provide the necessary evidence to support or refute this common clinical practice and subsequent clinical decision making. Thus, we evaluated preoperative data from a large, multicenter FDA clinical trial for a middle ear implant, including word recognition measured using earphones and word recognition measured in the sound field in unaided and aided conditions. The primary goal was to determine associations among these three measurements and provide information needed for evidence-based practice.

METHODS

Data for this analysis were obtained from the multicenter Phase III FDA clinical trial for the Soundtec Direct Drive Hearing System, which is now known as the Maxum Hearing Implant (Ototronix, Houston, TX). Results for the current analyses were computed from raw values from individual study participants, which had been previously submitted to the FDA. A Material Transfer Agreement was signed between our institution and the Ototronix Company before deidentified data were shared with the authors. Ototronix personnel did not participate in any experimental planning or analysis of data, nor did they review drafts of publications before journal submission.

Inclusion Criteria

Study participants in the FDA clinical trial were required to be 21 to 80-year-old fluent English speakers with >2 year history of hearing loss without fluctuation. They were required to have bilateral symmetrical sensorineural hearing loss with pure-tone averages (PTA; average of thresholds at 1000, 2000, 4000 Hz) for left and right ears <15 dB. Inclusion criteria for pure-tone thresholds were the following ranges: 0 to 50 dB HL at 250 Hz, 0 to 60 dB HL at 500 Hz, 10 to 70 dB HL at 1000 Hz, 35 to 75 dB HL at 2000 Hz, 50 to 75 dB HL at 3000 Hz, 50 to 80 dB HL at 4000 Hz, and 40 to 100 dB HL at 6000 Hz, with PTA ranging from 35 to 70 dB HL. Bone conduction thresholds were required to be within 10 dB of air conduction thresholds. Word recognition scores measured under earphones in quiet using 50-word lists from the Northwestern University Test Number 6 (NU-6) (16) were required to be >60% in both ears. The poorer hearing ear was selected as the test ear.

Exclusion Criteria

Candidates with the following pathologies were excluded from the study: otitis media, otitis externa, tympanic membrane perforation, otosclerosis, retrocochlear pathology, and disabling tinnitus. Candidates with previous middle ear surgery were also excluded.

Hearing Aids

Participants were required to have at least 6 months of hearing aid use prior to enrollment. Hearing aids for all participants were fit by study audiologists according to NAL-R (17) gain targets prior to testing. Individuals who met study inclusion criteria but whose hearing aids were not consistent with NAL-R targets had the necessary adjustments made by study audiologists during their first visit. Candidates were then required to use their newly programmed hearing aids at least 45 days before enrollment.

Study Test Battery

Among a large battery of measurements required for the FDA clinical trial, word recognition using NU-6 word lists in quiet was measured under three conditions: earphone (unaided with either supra-aural headphones or insert earphones) at 40 dB SL re: SRT, unaided in the sound field with NU-6 words presented at 63 dB SPL, and aided in the sound field with NU-6 words presented at 63 dB SPL. For the remainder of the paper, the terms earphone, unaided, and aided will refer to the above three conditions.

Sound field testing was performed in sound attenuated booths that met ANSI standards for sound attenuation (18). Participants sat 1 m at 0 degree azimuth from the loudspeaker. The nontest ear was occluded with a foam plug during testing. In addition to word recognition measures, unaided and aided thresholds in the sound field using warble tones were obtained at frequencies ranging from 250 to 6000 Hz. The study test battery also included measurements of air conduction pure-tone thresholds under earphones at frequencies ranging from 250 to 8000 Hz and bone conduction pure tone thresholds at frequencies from 250 to 4000 Hz.

Earphone to Aided Difference

For the purpose of this analysis, the ''earphone to aided difference'' (EAD) was defined as the word recognition score (in percent) in the earphone condition *minus* the score (in percent) in the aided condition. Thus, positive values (+EAD) indicate that word recognition scores were higher in the earphone condition than in the aided condition. Negative or zero values (−EAD) indicate that word recognition scores were equal or lower in the earphone condition than in the aided condition.

Speech Intelligibility Index

Given the large differences in speech levels used to obtain word recognition scores for earphone, unaided, and aided conditions, we hypothesized that differences in scores between +EAD and −EAD groups and between conditions may be explained by differences in speech audibility. To test this hypothesis, weighted-average speech audibility and predicted scores for NU-6 words for earphone, unaided, and aided conditions were computed for each participant using the Speech Intelligibility Index (SII), with procedures similar to ANSI (1997) (19).

Statistical Analyses

Statistical analyses were performed using StatPlus (AnalystSoft, Inc., Walnut, CA). Comparisons of demographic and audiologic characteristics of participants in the +EAD and −EAD groups were conducted using either paired or unpaired

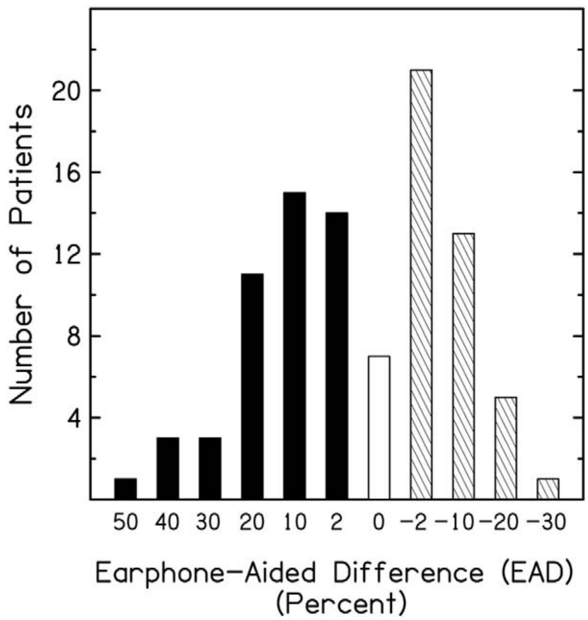

FIG. 1. Number of participants for a given increment of +EAD and −EAD (in percent). Each *histogram bar* includes a range from its numerical value to the next positive value for +EAD and to the next negative value for −EAD. For example, the bar labeled "2" includes EAD values from 2% to 8% and the bar labeled "−10" includes −EAD values from −10% to −18%. EAD indicates "earphone to aided difference."

t tests (continuous, normally distributed data) as appropriate. Linear regression models were used to assess correlations among earphone, unaided, and aided word recognition scores.

RESULTS

A total of 95 individuals met all inclusion and exclusion criteria and were enrolled in the FDA trial. Data from one participant were excluded from the current analyses due to word recognition scores in the aided condition that were more than 3 standard deviations from the mean. Mean age of the 94 participants was 65.0 years (range, 24.2−80.9 yr). Mean duration of hearing loss was 15 years, mean duration of hearing aid use was 7.2 years, and mean duration of current hearing aid use was 3.5 years.

Earphone to Aided Difference

Of 94 study participants, word recognition scores for 50% of participants (N = 47) were higher in the earphone condition than in the aided condition. The difference between scores for earphone and aided conditions was <10% for 42 (44.7%) participants; score differences were >10% for the remainder (52 participants, 55.3%). Figure 1 displays the EAD distribution for the study sample. The number of participants in the +EAD and −EAD groups was equal (N = 47 for each group, see Table 1). For 33 participants (35.1%), earphone scores were higher by 10% or more than aided scores (+EAD≥10%) and, for 18 participants (19.1%), earphone scores were higher by 20% or more than aided scores (+EAD≥20%). For 19 participants (20.2%), earphone scores were lower by 10% or more than aided scores (−EAD≥10%) and, for six participants (6.4%), earphone scores were lower by 20% or more than aided scores (−EAD≥20%).

TABLE 1. *Demographic comparison of +EAD and −EAD groups*

	+EAD	−EAD	*p* Value
N	47	47	
Age (yr)	66.5	63.4	0.18
Duration of hearing loss (yr)	14.5	15.6	0.61
Duration of hearing aid use (yr)	7.3	7.1	0.85
Duration current hearing aid use (yr)	3.1	3.9	0.24

EAD indicates ''earphone to aided difference.''

Comparisons of +EAD and −EAD Groups

We found no statistically significant differences in demographic characteristics between participants in the +EAD and −EAD groups, specifically age, duration of hearing loss, and duration of hearing aid use (Table 1). However, significant differences in some audiometric measures between +EAD and −EAD groups were found (Table 2). For example, participants in the +EAD group (higher scores in the earphone than aided condition) also had significantly higher pure-tone thresholds at 250, 500, and 1000 Hz (Fig. 2 and Table 2), higher PTAs (average of thresholds at 500, 1000, and 2000 Hz), and higher SRTs than the −EAD group (all $p < 0.05$). Given that speech levels used for word recognition were set to a fixed level above the SRT (+40 dB) for all participants, the mean earphone speech level was also significantly higher in the +EAD group than in the −EAD group (82.2 dB HL versus 74.6 dB HL; $p = 0.002$; see Table 1). As shown in Figure 3, as expected given these differences

TABLE 2. *Audiologic comparison of +EAD and −EAD groups*

		+EAD	−EAD	*p* Value
Pure-tone threshold (dB HL)	250	28.19	23.2	0.05
	500	32.23	25.1	0.007
	1,000	42.98	34.9	0.002
	2,000	55.21	54.1	0.54
	3,000	60.53	63.0	0.11
	4,000	64.68	66.7	0.25
	6,000	68.72	70.4	0.053
	8,000	72.45	72.8	0.91
PTA (dB HL)		43.5	38.0	0.002
SRT (dB HL)		42.2	34.6	0.002
Earphone presentation level (dB HL)		82.2	74.6	0.002
Word recognition earphone (%)		85.8%	77.1%	<0.001
Word recognition (%) unaided		30.9%	54.8%	<0.001
Word recognition aided (%)		68.5%	86.4%	<0.001
EAD (%)		17.4%	−9.3%	<0.001

EAD indicates ''earphone to aided difference''; PTA, pure-tone average; SRT, speech recognition threshold.

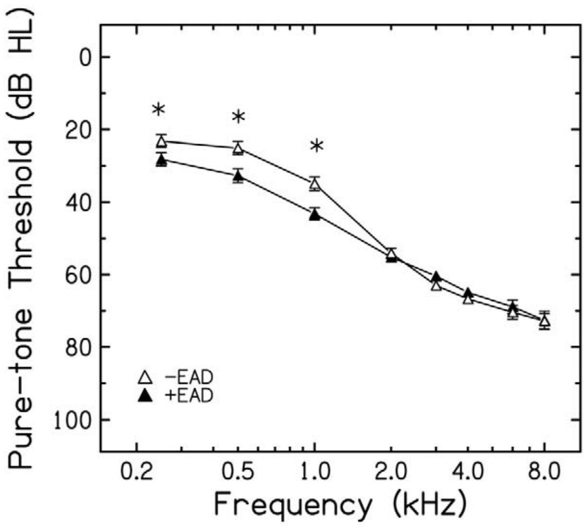

FIG. 2. Mean pure-tone thresholds for the +EAD and −EAD groups with *error bars* indicating ±1 standard error at each frequency. Statistically significant differences in pure-tone thresholds were found at 250, 500, and 1000 Hz (*asterisks*, all $p < 0.05$).

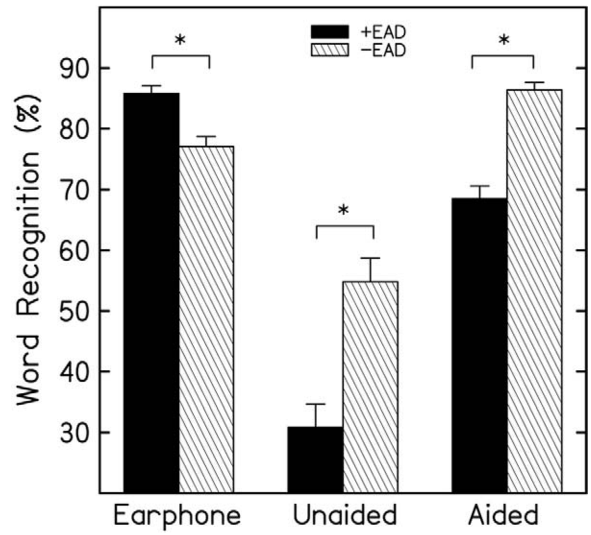

FIG. 3. Mean word recognition scores in the earphone, unaided, and aided conditions for +EAD and −EAD groups with *error bars* indicating +1 standard error for each condition. *Asterisks* denote differences at $p < 0.001$.

in speech levels, word recognition scores in the earphone condition were significantly higher in the +EAD group than in the −EAD group (85.8% versus 77.1%, $p < 0.001$). Also as expected due to the use of a fixed 63 dB SPL sound field speech level for all participants, word recognition scores measured in the sound field were significantly lower in the +EAD group than in the −EAD group, especially in the unaided condition (30.9% versus 54.8%; $p < 0.001$), but also in the aided condition (68.5% versus 86.4%, $p < 0.001$).

Figure 3 also displays differences in scores in the earphone (SRT+40 dB), unaided (63 dB SPL), and aided (63 dB SPL + hearing aid gain) conditions for the +EAD and −EAD groups. Scores were significantly higher for the earphone than aided condition for the +EAD group, whereas scores were significantly lower for the earphone than aided condition for the −EAD group (both $p < 0.001$). Both groups had statistically significant hearing aid benefit, that is, improvement in scores between unaided and aided conditions ($p < 0.001$); no difference in hearing aid benefit was found between the +EAD and −EAD groups (37.6% versus 31.6%; $p = 0.17$).

Predicting Aided Word Recognition

Figure 4 shows scores in the aided condition plotted against scores in the earphone condition (left panel) and scores in the unaided condition (right panel). Note that scores for the earphone condition were relatively high for most participants, as would be expected due to the relatively high speech levels and the requirement that all participants achieve earphone scores >60%. Similarly, scores for the aided condition were relatively high for most participants due to the amplification provided by hearing aids, although aided scores for five participants were <50%. The correlation between scores in the earphone and aided conditions was not statistically significant ($r = .14$; $p = 0.16$), which may be partially attributed to the restricted ranges of scores. In contrast, unaided scores ranged from 0 to 92% and a moderately high positive correlation was observed between these scores and scores in the aided condition ($r = 0.68$; $p < 0.001$). That is, scores in the unaided condition accounted for 46.2% of the variance in scores in the aided condition. Note also that the five participants whose aided scores were <50% had unaided scores of 0%, 0%, 0%, 8%, and 16% and were among participants with relatively high PTAs (ranging from 41.7 to 51.6 dB HL).

Speech Intelligibility Index

Figure 5 shows word recognition scores plotted against SII (or, weighted speech audibility); the solid line is the predicted score and the dashed lines encompass the 95% confidence limit. The left panel includes scores and SIIs for earphone and aided conditions; the right panel includes scores and SIIs for unaided and aided conditions. These results clearly show the wide range of speech audibility for the 94 participants (as indicated by SII values) and the substantially higher speech audibility and word recognition in the earphone condition and with hearing aids as compared with the unaided condition. Overall, a majority of participants performed as expected for their hearing loss and associated speech audibility in earphone, unaided, and aided conditions (i.e., within the 95% confidence limit). Approximately the same number of participants performed poorer than predicted in the three conditions (i.e., below the lower confidence limit). Of the 18 participants with +EAD ≥20% (i.e., earphone scores higher than aided scores by 20% or more), 14 performed poorer than predicted in the aided condition,

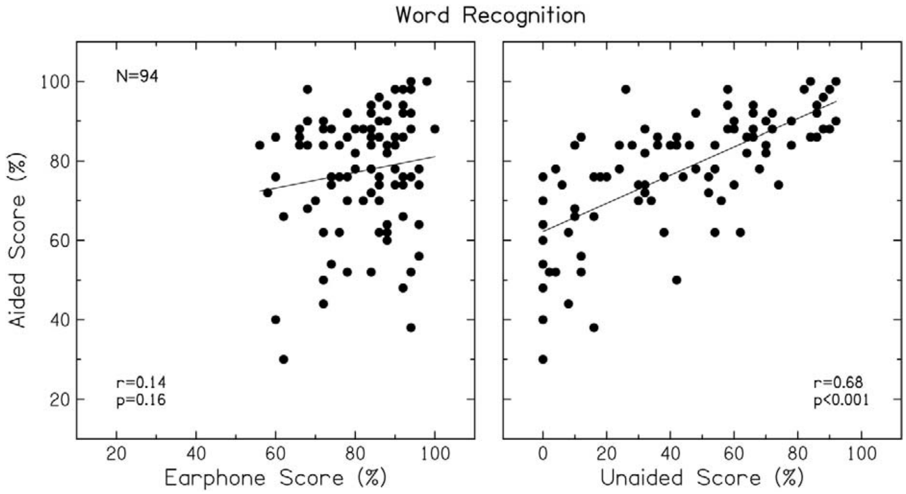

FIG. 4. Aided word recognition scores (in percent) plotted against earphone (*left*) and unaided (*right*) scores. The correlation between earphone and aided word recognition scores was not statistically significant ($r = 0.14$; $p = 0.16$), whereas a moderately high positive correlation was observed between unaided and aided word recognition scores ($r = 0.68$; $p < 0.001$).

which is additional evidence of the poor predictive value of relatively high earphone scores. Of those, 10 also performed poorer than predicted in the unaided condition and 4 performed poorer than predicted in the earphone condition. Results in Figure 5 are also consistent with the assumption that differences in word recognition between earphone and aided conditions are driven primarily by differences in speech levels and associated speech audibility, rather than by the method of delivery of the signals.

DISCUSSION

From these analyses, it is evident that word recognition scores measured under earphones at high levels (e.g., SRT +40 dB) are poor predictors of word recognition with hearing aids. Overall, word recognition for more than half the participants differed by >10% between earphone and aided conditions. Of these individuals, scores for a majority (63.5%) were more than 10% higher (+EAD ≥10%) in the earphone condition than in the aided condition, primarily because speech levels were higher for the earphone condition than with hearing aids.

The identification and interpretation of the EAD represent significant challenges to clinical audiology and otolaryngology. Clinicians typically assume that patients whose word recognition (measured with earphones) is >60% should perform well with hearing aids. However, because word recognition measured under earphones provides little predictive information, clinicians cannot estimate with accuracy the communication abilities of their patients who may be interested in using hearing aids and, therefore, do not have the information needed to make evidence-based recommendations.

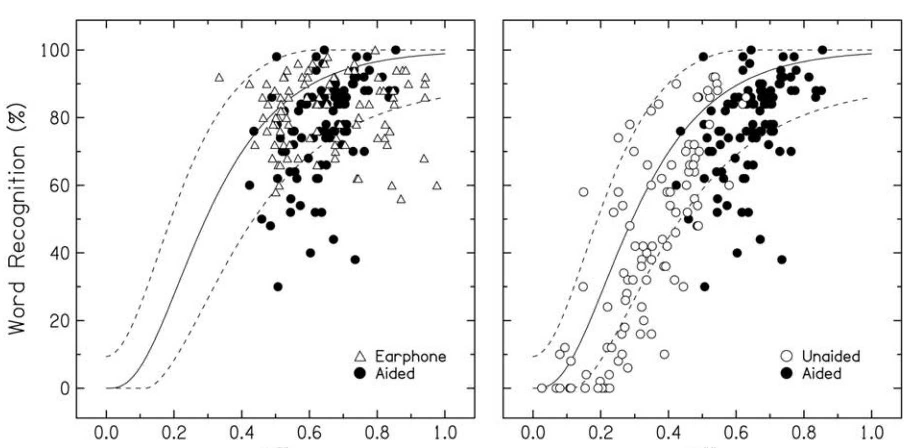

FIG. 5. Word recognition scores plotted against the Speech Intelligibility Index (SII). The *solid line* is the predicted score and the *dashed lines* encompass the 95% confidence limit. The *left panel* includes scores and SIIs for earphone and aided conditions; the *right panel* includes scores and SIIs for unaided and aided conditions. The majority of patients performed as expected without and with their hearing aids given their hearing loss and speech level.

Without accurate methods of estimating hearing aid benefit from available clinical results, aided word recognition should be measured directly.

Patients with hearing loss are advised to follow the progression of their hearing loss and communication abilities with an annual audiologic test battery. As long as word recognition measured under earphones remains at ~60% or better, patients are typically advised to continue with their hearing aids. It is only after word recognition scores decline to the point that cochlear implant candidacy is considered is aided word recognition measured directly.

As discussed earlier, word recognition for 18 participants (19.1%) was ≥20% higher in the earphone condition than in the aided condition (+EAD ≥20%). With mean word recognition of 84.0% in the earphone condition, it is likely that patients such as these would be (incorrectly) considered excellent hearing aid candidates, even though their mean aided scores were 53.8%. As noted earlier, aided scores for five of these participants, ranging from 30 to 50%, would qualify them as cochlear implant candidates. These results provide strong evidence for the measurement of aided word recognition in patients who are considering hearing aids. Measuring aided word recognition provides more insight into patients' listening experience, can more accurately predict hearing aid benefit, and can better guide subsequent interventions, such as counseling and auditory training. Knowledge of aided word recognition can also inform decisions related to hearing aid styles and programming, and alternative interventions, such as a middle ear or cochlear implant.

The identification of the EAD revealed an important limitation in the measurement of word recognition with earphones. We hypothesized that EAD can be attributed primarily to differences in speech levels between earphone and aided conditions. Based on SII results (Fig. 5), most participants performed as expected with their hearing aids given their hearing loss and associated speech audibility. In addition, a moderately high positive correlation ($r = 0.68$) was observed between unaided and aided word recognition (Fig. 4), along with significant and expected improvement in word recognition from the unaided to aided condition (Fig. 3), which was equivalent for +EAD and −EAD groups.

In this study, as often in clinical practice, speech levels for word recognition measured with earphones were set at a fixed level above SRT (e.g., 30–40 dB SL re: SRT). As a result, speech levels are higher for patients with higher thresholds (higher SRTs), which can result in higher earphone word recognition scores. However, as demonstrated here with the EAD, higher earphone word recognition scores may not necessarily correspond to higher aided word recognition. Participants in the +EAD group had significantly higher thresholds at 250, 500, and 1000 Hz, higher PTAs, and higher SRTs compared with participants in the −EAD group. These higher thresholds corresponded to 7.6 dB higher average speech levels for the earphone condition for the +EAD group than the −EAD group and higher word recognition scores (85.8% versus 77.1%, $p < 0.0001$). For unaided and aided word recognition, both groups received the same lower input level of 63 dB SPL, where scores for the +EAD group were poorer than for the −EAD group, as predicted by the SII.

Substantial previous research has been conducted to define optimal methods for measuring word recognition with earphones, with the goal of identifying a patient's maximum recognition score (10,14,20). Guthrie and Mackersie evaluated several methods, including SRT +10 dB and uncomfortable level (UCL), and concluded that maximum word recognition scores were obtained at UCL-5 dB in patients with hearing loss (10). Nevertheless, the relevance of the earphone measure to clinical practice remains in question. Hoppe et al. previously reported that only 40% of patients achieved aided word recognition within 10% of earphone measures, which is consistent with our current findings of 47.7% (21). Thus, given that maximum scores obtained with earphones may not accurately predict aided word recognition, perhaps a more appropriate clinical application (and its original use (22)) for the maximum score is to identify left-right asymmetries or disproportionately poor scores (14), which may relate to possible retrocochlear pathology, and to identify individuals with nonserviceable hearing loss. For estimating functional communication abilities and hearing aid benefit, a different approach to setting levels for word recognition measured with earphones can be considered, such as selecting one lower speech level (similar to unaided listening) and one higher speech level (similar to aided listening). Scores should increase appropriately with increasing level due to improved speech audibility; using simple software, observed scores at each level can easily be compared to scores predicted using the SII. More research is needed to provide evidence of the clinical utility of this procedure, along with other important methods for estimating functional communication abilities, such as using measures of speech recognition in noise (23).

The current results demonstrate the importance of regularly assessing unaided and aided word recognition in the clinical setting. Word recognition measured in the unaided condition provides a predictor of patient's aided benefit. Measurement of scores with hearing aids allows clinicians to better understand hearing aid users' listening and communication abilities and guides plans for any necessary changes to improve the quality of the patient's communication. These changes may ultimately lead to improved hearing aid satisfaction and use and evidence-based decisions for if and when patients should consider alternative treatments, such as middle ear or cochlear implants.

The main limitation of this study is that participants enrolled in the FDA trial were interested in middle ear implants, presumably due to dissatisfaction with their hearing aids. Interestingly, even in this sample, substantial improvement in word recognition was observed between the unaided and aided conditions; word recognition for most participants was equivalent to scores predicted for their hearing loss and speech levels. Demographics and audiologic results were also similar to typical hearing aid candidates and users, which supports the assumption that participants in the current study are representative of the middle-aged to older adult population with hearing loss.

CONCLUSIONS

In evaluating preoperative results from an FDA trial for a middle ear implant, we found that word recognition scores for the majority of hearing aid users were as expected given their hearing loss and speech levels. No significant correlation was observed between word recognition scores measured with earphones and with hearing aids, whereas a moderately high positive correlation was observed between unaided and aided word recognition scores. These results do not support the common clinical practice of using word recognition scores measured with earphones to predict aided word recognition or hearing aid benefit. Rather, these results provide evidence supporting the measurement of aided word recognition in patients who are considering hearing aids.

REFERENCES

1. Mathers C, Smith A, Concha M. Global burden of hearing loss in the year 2000. *Global Burden Dis* 2000;18:1–30.
2. Yueh B, Shapiro N, MacLean CH, Shekelle PG. Screening and management of adult hearing loss in primary care: Scientific review. *JAMA* 2003;289:1975–86.
3. Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I. Acceptability, benefit and costs of early screening for hearing disability: A study of potential screening tests and models. *Health Technol Assessment* 2007;11:1–294.
4. Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing loss and incident dementia. *Arch Neurol* 2011;68:214–20.
5. Mulrow CD, Aguilar C, Endicott JE, et al. Quality-of-life changes and hearing impairment: A randomized trial. *Ann Internal Med* 1990;113:188–94.
6. Mulrow CD, Aguilar C, Endicott JE, et al. Association between hearing impairment and the quality of life of elderly individuals. *J Am Geriatr Soc* 1990;38:45–50.
7. Uhlmann RF, Larson EB, Koepsell TD. Hearing impairment and cognitive decline in senile dementia of the Alzheimer's type. *J Am Geriatr Soc* 1986;34:207–10.
8. Palmer CV, Adams SW, Bourgeois M, Durrant J, Rossi M. Reduction in caregiver-identified problem behaviors in patients with Alzheimer disease post-hearing-aid fitting. *J Speech Lang Hear Res* 1999;42:312–28.
9. American Speech-Language-Hearing Association. Determining threshold level for speech [Guidelines]. 1988. Available at: www.asha.org/policy. Accessed January 7, 2016.
10. Guthrie LA, Mackersie CL. A comparison of presentation levels to maximize word recognition scores. *J Am Acad Audiol* 2009;20: 381–90.
11. Beattie RC, Raffin MJ. Reliability of threshold, slope, and PB max for monosyllabic words. *J Speech Hear Disord* 1985;50: 166–78.
12. Beattie RC, Zipp JA. Range of intensities yielding PB max and the threshold for monosyllabic words for hearing-impaired subjects. *J Speech Hear Disord* 1990;55:417–26.
13. Boothroyd A. The performance/intensity function: An underused resource. *Ear Hear* 2008;29:479–91.
14. Dubno JR, Lee FS, Klein AJ, Matthews LJ, Lam CF. Confidence limits for maximum word-recognition scores. *J Speech Hear Res* 1995;38:490–502.
15. Martin FN, Champlin CA, Chambers JA. Seventh survey of audiometric practices in United States. *J Am Acad Audiol* 1998;9:95–104.
16. Tillman TW, Carhart R. An expanded test for speech discrimination utilizing CNC monosyllabic words. Northwestern University Auditory Test No. 6. Tech Re SAM-TR. 1966:1–12.
17. Byrne D, Dillon H. The national acoustics laboratories' (NAL) new procedure for selecting gain and frequency response of a hearing aid. *Ear Hear* 1986;7:257–65.
18. American National Standards Institute. *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*. New York: ANSI; 2008. S3.1-1999 (R2008).
19. American National Standards Institute. *American National Standard Methods for Calculation of the Speech Intelligibility Index*. New York: ANSI; 2007. S3.5-1997 (R2012).
20. Kamm CA, Dirks DD, Mickey MR. Effect of sensorineural hearing loss on loudness discomfort level and most comfortable loudness judgments. *J Speech Hear Res* 1978;21:668–81.
21. Hoppe U, Hast A, Hocke T. Audiometry-based screening procedure for cochlear implant candidacy. *Otol Neurotol* 2015; 36:1001–5.
22. Jerger J, Jerger S. Diagnostic significance of PB word functions. *Arch Otolaryngol* 1971;93:573–80.
23. Wilson RH. Clinical experience with the words-in-noise test on 3,430 veterans: Comparisons with pure-tone thresholds and word recognition in quiet. *J Am Acad Audiol* 2011;22:405–23.