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Research Forum

Examination of Individual Differences in Outcomes From a Randomized Controlled Clinical Trial Comparing Formal and Informal Individual Auditory Training Programs

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Purpose: The purpose of this study was to determine if patient characteristics or clinical variables could predict who benefits from individual auditory training.
Method: A retrospective series of analyses were performed using a data set from a large, multisite, randomized controlled clinical trial that compared the treatment effects of at-home auditory training programs in bilateral hearing aid users. The treatment arms were (a) use of the 20-day computerized Listening and Communication Enhancement program, (b) use of the 10-day digital versatile disc Listening and Communication Enhancement program, (c) use of a placebo "books-on-tape" training, and (d) educational counseling (active control). Multiple linear regression models using data from 263 participants were conducted to determine if patient and clinical variables predicted short-term improvement on word-recognition-in-noise abilities, self-reported hearing handicap, and self-reported hearing problems.
Results: Baseline performance significantly predicted performance on each variable, explaining 11%–17% of the variance in improvement. The treatment arm failed to emerge as a significant predictor with other clinical variables explaining less than 9% of the variance.
Conclusion: These results suggest that hearing aid users who have poorer aided word-recognition-in-noise scores and greater residual activity limitations and participation restrictions will show the largest improvement in these areas.

Amplification is the primary rehabilitative option used to treat the effects of hearing loss. At the group level, patient outcomes from modern-day hearing aid use are positive (e.g., Cook & Hawkins, 2007; Kochkin, 2005, 2010; Larson et al., 2000). Many individuals, however, do not achieve optimal hearing aid outcomes (e.g., Edwards, 2007; Kochkin, 2010). For these individuals, additional audiologic rehabilitation above and beyond amplification may be warranted. One audiologic rehabilitation approach that has received renewed attention is auditory training (AT), which can be done at home with computer-based programs. AT consists of exercises whereby the listener engages in perceptual learning of sounds or speech (e.g., Schow & Nerbonne, 2007; Stecker et al., 2006). AT can be structured such that the stimuli, skill, and difficulty levels systematically are manipulated, whereas other training also can be more informal in nature (Olson & Canada, 2013). In addition, AT may incorporate analytic (bottom-up) approaches that focus on discrimination and/or recognition of consonants and vowels and/or synthetic (top-down) approaches, meaning that the exercises focus on listening skills at the sentence level along with training on the use of linguistic and situational cues to improve speech understanding (Rubinstein & Boothroyd, 1987; Schow & Nerbonne,

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2007). Several studies have been conducted over the past decade to determine the efficacy, effectiveness, and efficiency of computer-based AT programs (e.g., Anderson, White-Schwoch, Choi, & Kraus, 2013; Barcroft et al., 2011; Burk & Humes, 2008; Burk, Humes, Amos, & Strauser, 2006; Dubno, 2013; Ferguson, Henshaw, Clark, & Moore, 2014; Humes, Burk, Strauser, & Kinney, 2009; Olson, Preminger, & Shinn, 2013; Saunders et al., 2016; Song, Skoe, Banai, & Kraus, 2011; Stecker et al., 2006; Sweetow & Sabes, 2006).

Three systematic reviews (Chisolm & Arnold, 2012; Henshaw & Ferguson, 2013; Sweetow & Palmer, 2005) and a meta-analysis (Chisolm & Arnold, 2012) have been conducted to determine if AT, either face to face or computer based, leads to improvements in speech understanding and/or in subjective outcomes. Together, these reviews were based on an examination of 12 unique (non-cochlear implant) studies conducted between 1970 and 2011. The converging evidence from the three systematic reviews suggests that there are data supporting AT in laboratory conditions (efficacy) but that less evidence is available to support the use of AT from clinical/field trials (effectiveness), particularly for measures of speech recognition. More robust improvements with individual AT, however, were found from synthetic (top-down) rather than analytic (bottom-up) training approaches (efficiency; Sweetow & Palmer, 2005). The evidence also suggests that greater improvements are seen for trained relative to untrained stimuli and talkers, suggesting that training may not generalize or transfer to real-world listening. At this time, the evidence indicates that clinical recommendations for individual AT in adults is suggestive at best, meaning that clinicians can choose to include individual AT as part of their postamplification audiologic rehabilitation repertoire, but the overall gains in speech recognition would be small for the average patient (Chisolm & Arnold, 2012).

One potential reason that robust treatment effects at the group level have not been realized with AT is that individual differences have not been fully taken into account. For example, examination of studies that report individual data show that treatment effects can be null, small, or even negative for some individuals, whereas others enjoy a large benefit following the completion of AT programs (e.g., Humes et al., 2009). As such, at the group level the large individual differences in treatment effects can reduce the magnitude of the overall group findings. Thus, it would be helpful to identify factors that would determine what patients might benefit from AT and what patients might not (Abrams & Chisolm, 2013; Chisolm & Arnold, 2012; Dubno, 2013; Saunders, 2012; Saunders et al., 2016).

Several studies reporting AT outcomes also have reported on statistical efforts to identify predictors of AT benefit. Humes et al. (2009); Kricos and Holmes (1996); Stecker et al. (2006); and Walden, Erdman, Montgomery, Schwartz, and Prosek (1981), for example, have each reported that baseline performance is a predictor of benefit from AT. Data suggest that listeners with poorer baseline performance realize larger gains from AT than those with better baseline performance. This may be due to the fact that the largest gains in performance are observed in those individuals who have the most to gain (i.e., when ceiling effects are not encountered). It is unfortunate that most of the above studies, aside from that of Kricos and Holmes, did not have a no-treatment control group, and thus improvements from treatment relative to a no-intervention group could not be examined. Age has been shown to be predictive of benefit from AT in some studies (Bode & Oyer, 1970; Humes et al., 2009; Stecker et al., 2006), with older participants showing greater benefit than younger participants. Other studies, however, have not supported age as a predictor (e.g., Dubno, 2013). Likewise, cognition appears to be a mixed predictor of AT benefit, with Bode and Oyer (1970) finding a measure of vocabulary to be predictive of outcome and Dubno (2013) finding general cognitive abilities were not. Hearing aid user status was shown by Olson et al. (2013) to be associated with outcomes from AT, with new hearing aid users showing larger gains in speech recognition and self-reported outcomes relative to experienced hearing aid users following AT. Olson et al., however, attributed this finding to acclimatization rather than to AT. Various other predictors of benefit from AT have been suggested, such as motivation to train (Montgomery, Walden, Schwartz, & Prosek, 1984; Sweetow & Sabes, 2006) and compliance with training (Chisolm et al., 2013; Sweetow & Sabes, 2010). Self-efficacy and enjoyment with training are promising predictor variables as well (Tye-Murray et al., 2012).

Abrams and Chisolm (2013) noted that, in general, many AT studies have not considered individual differences in outcomes and urged that further research in this area is needed so that clinicians can provide more appropriate recommendations regarding the use of individual AT programs for a given patient. To this end, the purpose of the present study was to evaluate data from a large, multisite randomized controlled trial (RCT; described below) to determine if there are clinical predictors of benefit from at-home AT programs. One speech-in-noise and two self-report hearing measures were used as outcomes in the current study. The predictor variables selected for the analyses were chosen because they would be available to or easily obtainable by clinicians, and they also were available in the RCT data set.

Method

This study consisted of retrospective analyses of an existing data set from a previous multisite RCT. See Saunders et al. (2016) for more details. A brief overview is provided below.

Brief Overview of the Multisite RCT

The purpose of the RCT was to determine if at-home AT with the Listening and Communication Enhancement (LACE; Sweetow & Sabes, 2006) programs (computer based or DVD based) as a supplement to hearing aid intervention were more effective than placebo training or

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simply providing a single session of educational counseling (control). A total of 279 new and experienced bilateral hearing aid users participated. The participants were older Veterans (mean age = 68.6 years, *SD* = 7.7 years) with pure-tone averages (500, 1000, and 2000 Hz) ≤ 50 dB HL (American National Standards Institute, 2004) who wore appropriately fitted hearing aids that were current (defined as still in production by hearing aid manufacturers at the time of the study enrollment). The participants randomly were assigned to one of four treatment arms: (a) the 20-day computerized LACE (LACE-C) program, (b) 10-day LACE training completed with a DVD (LACE-DVD), (c) 20-day a computerized "books-on-tape" training (placebo), and (d) an active control group. Participants in the placebo group received a "books-on-tape" intervention whereby they actively listened to a book presented via a computer software program for 20 sessions, 30 min each, while answering questions about the story's content throughout the training. The placebo training thus was considered an informal AT training program because the participants engaged in a semistructured program. Participants in the LACE-C, LACE-DVD, and placebo groups were loaned equipment (laptops or DVD players) in order to perform their respective interventions at home and thus received an orientation by the study audiologist on how to set up the equipment. This orientation lasted approximately 30 min. In an effort to equate this one-on-one contact, the study audiologist provided participants in the control group with a 30-min educational counseling session on hearing loss. This counseling session consisted of a discussion of ear anatomy and how the auditory system works, a description of the audiogram, an explanation of the participant's hearing thresholds as plotted on the "speech banana audiogram," and a discussion of the limitations of hearing aids. Because the control group engaged in an educational session along with continued use of their amplification, their intervention could be considered a form of informal audiologic rehabilitation but not AT by some and thus could be considered an active control group (i.e., standard treatment group) rather than a no-treatment control group. Although the control group received a one-on-one educational session with the study audiologist, the nature of the education is unlikely to have influenced scores on the performance-based outcome measures.

The participants were seen for four study visits: Visit 1, preliminary testing to determine clinical characteristics and inclusion/exclusion testing; Visit 2, baseline outcome assessment and randomization to treatment arm, followed by an intervention period; Visit 3, immediate posttraining outcomes assessment; and Visit 4, a 6-month posttraining outcome assessment. Note that for the current research forum article, Visit 4 data were not examined.

The behavioral outcomes used in the RCT were selected to represent off-task assessments of the training modules targeted through LACE, many of which are not used routinely in clinical practice. Included in the study, however, were one speech-in-noise and two self-report hearing measures because they are used routinely by clinicians and thus may aid in decision making if AT is being considered. The most common goal of AT is improvement of speech perception; therefore, the primary outcome measure for the RCT was the Words-in-Noise test (WIN; Wilson, 2003; Wilson, Abrams, & Pillion, 2003). The WIN quantifies a listener's ability to understand monosyllabic words presented in a multitalker babble. The WIN consists of two lists that contain 35 words each. The level of the noise is constant, and the level of words descends to create seven signal-to-noise ratios (S/N) from 24 to 0 dB in 4 dB decrements. The WIN result is calculated with the Spearman–Kärber equation (Finney, 1952) and is expressed as the S/N at which 50% correct performance is achieved. WIN results ≤ 6 dB S/N are within the normal range, and 50% points that are > 6 dB S/N are considered outside of the normal range. The 95% critical difference (CD) score of 2.1 dB is required when both WIN lists (i.e., all 70 words) are administered and averaged together (Wilson & McArdle, 2007) as was done in the RCT to detect a true change in score from one test administration to another. The WIN was administered unaided at Visit 1 (preliminary screening) and aided at subsequent visits. Note that although the WIN is a word-based test, Wilson and McArdle (2007) showed performance on the WIN to be correlated with performances on the Quick Speech-in-Noise Test (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004), the Hearing in Noise Test (Nilsson, Soli, & Sullivan, 1994), and the Bench–Kowal–Bamford Speech-in-Noise Test (Niquette et al., 2003).

Two commonly used self-reported measures were administered as secondary outcome measures in the RCT. They were the Hearing Handicap Inventory for Adults/Elderly (HHIA/E; Newman, Weinstein, Jacobson, & Hug, 1990; Ventry & Weinstein, 1982) and the Abbreviated Profile of Hearing Aid Performance (APHAP; Cox & Alexander 1995). The HHIA/E is a 25-item measure whereby individuals quantify the emotional and social consequences of their hearing loss (HHIA for younger listeners [<65 years] and HHIE for older listeners [≥65 years]). The possible total scores range from 0 to 100 points with higher scores representing more self-reported consequences of hearing loss. The 95% CD score for the HHIE is 36 points (pen/paper administration; Weinstein, Spitzer, & Ventry, 1986) and 11.9 points for the HHIA (Newman, Weinstein, Jacobson, & Hug, 1991). The APHAP is a 24-item measure whereby individuals quantify the percentage of time they have problems while using their hearing aids in easy listening situations, background noise, reverberant environments, and also with aversiveness to loud sounds. The APHAP global score (average of all subscales except for aversiveness) was the variable used in the current study, and it ranges from 1% to 99% with higher scores indicating more problems. Cox and Alexander (1995) reported 95% CD scores for each speech communication subscale for the APHAP, which were 26% for ease of communication, 22% for reverberation, and 27% for background noise. Although 95% CD scores on the global scale were not reported, probability analyses were conducted, and the conclusion was that, for the three speech communication subscales (ease of communication,

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reverberation, and background noise) that make up the global scale, changes in aided scores of 5% or more would occur by chance in less than 9% of observations.

All three outcome measures used for analyses here were assessed at baseline prior to the intervention period and then again immediately following the intervention period at Visit 3. Additional outcome variables were assessed in the RCT that are not examined here because we are limiting our analyses to data that commonly would be available in a clinical setting.

Participants

The data set from the RCT originated with 279 participants at screening/baseline and 263 participants from the immediate postintervention period visit for whom outcomes were available. Of these 263 participants, 61 were in the LACE-C group, 63 were in the LACE-DVD group, 69 were in the placebo group, and 70 were in the control group. In addition, approximately half of the participants in each group were new hearing aid users (defined as having < 6 months of hearing aid experience), and the other half were experienced users (defined as having ≥ 6 months hearing aid experience). Specifically, 50.8% of the LACE-C group, 49.2% of the LACE-DVD group, 42.0% of the placebo group, and 52.9% of the control group were new hearing aid users.

Statistical Approach

For each outcome measure of interest (WIN, HHIA/E, APHAP), a change score was calculated. The change score was defined as the difference in outcome between the baseline assessment (Visit 2) and immediate postintervention (Visit 3). For ease of interpretation, change scores were calculated such that an improvement (i.e., better WIN performance, less activity limitation/participation restriction) was represented with a positive value, and a decline in performance was represented with a negative value.

A forward method multiple linear regression analysis was conducted separately for each outcome variable (WIN, HHIA/E, and APHAP) to determine if patient characteristics and/or clinical variables could predict change in performance following AT. The predictor variables selected were those that would readily be available or obtainable at a typical audiology visit and were representative of most predictor variables that have been examined previously. To be specific, the predictor variables selected were (a) age at the time of study enrollment (in years); (b) highest education level achieved (in years); (c) degree of motivation for improving hearing on a 1–10 scale with 1 representing *not at all motivated* and 10 representing *highly motivated*; (d) bilateral, high-frequency pure-tone average (HFPTA; average of 1000, 2000, and 4000 Hz); (e) unaided, bilateral word recognition in quiet made on the basis of a 25-word Northwestern University Auditory Test Number 6 (NU6; Tillman & Carhart, 1966) list administered with headphones; (f) unaided WIN 50% point threshold (dB S/N) in a sound field as described above; and (g) hearing aid user status (new or experienced). In order to examine the impact of intervention on outcome, treatment arm (LACE-C, LACE-DVD, placebo, control) was included as a predictor variable (dummy codes were used). In addition, baseline score on the outcome of interest (WIN, HHIA/E, and APHAP) was included as a predictor variable in the regression model when assessing change scores on that outcome (e.g., baseline WIN was included as a predictor variable for the regression predicting change on the WIN).

A forward method multiple linear regression analysis uses the potential predictor variables to identify the variable that best predicts the outcome (short-term change in our case) on the basis of a correlation, then "searches" for additional predictor variables that explain a significant amount of variance in the outcome. Only those variables that significantly contribute to the variance in outcome are retained in the final model. Variance inflation factors (VIFs) were used to examine collinearity between predictors with a threshold for further investigation of collinearity set to a VIF value of 10.0 (Field, 2009).

Results

Table 1 displays the means (and standard deviations) for performance on the continuous predictor variables as a function of treatment arm for the 263 participants. As reported by Saunders et al. (2016), analyses of variance and chi-square testing revealed that the treatment arms were equivalent in terms of age, HFPTA (better ear), NU6 scores, unaided WIN thresholds, and hearing aid user status. Results of analyses of variance from the current study comparing scores across treatment arms for motivation, education level, baseline WIN, baseline HHIA/E, and baseline APHAP also showed the groups were equivalent on these measures ($p > .05$).

Table 2 displays the average change scores (and other descriptors) for the WIN, HHIA/E, and APHAP as a function of treatment arm as well as all groups combined. As a reminder, each change score is the difference between baseline performance and immediate postintervention period performance computed such that a positive change score indicates improved scores and vice versa. The change score was the outcome measure in each regression model. A key point here is that the average change in each variable was negligible although the data showed variability. In addition, not all change scores exceeded the 95% CD scores mentioned earlier and provided in the literature. The number and percentage of participants who had positive or negative change scores that exceed the CD scores for the three outcomes measures are displayed in Table 3. For the WIN and HHIA/E, less than 20% of the participants' change scores exceeded the CD criteria for the respective measures, and slightly more than half of the participants did so for the APHAP.

Regression Models

For each regression analysis, VIFs were computed to look for the presence of collinearity. When below 10.0,

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Table 1. The means and standard deviations for the continuous predictor variables for the four treatment arms.

Variable	LACE-C		LACE-DVD		Placebo		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Demographic/clinical								
Age (years)	68.7	8.0	68.0	7.7	67.5	7.7	70.2	7.2
Education (years)	12.8	1.6	13.0	1.2	13.1	1.3	13.0	1.2
Motivation (1–10)	9.2	1.3	9.4	1.2	9.2	1.4	9.4	1.3
HFPTA (dB HL)	47.6	9.3	48.4	9.1	48.4	9.6	48.2	10.4
NU6 (%)	89.2	12.2	88.7	10.9	89.1	9.0	85.6	11.9
Unaided WIN (dB S/N)	10.6	3.3	10.9	3.3	11.0	3.3	11.8	3.6
Baseline performance								
Aided WIN (dB S/N)	9.8	2.7	9.7	2.2	9.8	2.4	10.4	2.3
Aided HHIA/E (points)	31.3	22.4	28.7	22.3	30.2	20.7	33.0	21.2
Aided APHAP (%)	32.3	18.9	31.6	16.9	33.0	15.4	36.4	18.8

Note. LACE-C = Listening and Communication Enhancement–computerized; LACE-DVD = Listening and Communication Enhancement–DVD based; HFPTA = high-frequency pure-tone average; NU6 = Northwestern University Auditory Test Number 6; WIN = Words-in-Noise test; S/N = signal-to-noise ratio; HHIA/E = Hearing Handicap Inventory for Adults/Elderly; APHAP = Abbreviated Profile of Hearing Aid Performance.

VIFs are considered inconsequential to regression outcomes (Field, 2009). Across the three regressions here, the VIFs ranged from 1.023 to 1.592; thus, collinearity among the potential predictors was not a problem.

WIN

Table 4 (top portion) displays the regression results of the WIN outcome change scores. The variables that were retained in the final model were baseline WIN, bilateral HFPTA, and bilateral unaided NU6 scores in quiet (see *p* values under the coefficient summary statistics section), $F(3, 258) = 23.8$, $p < .001$. Taken together, these three variables predicted 21.7% of the variance in change scores on the WIN. Of the variance explained in the model, baseline WIN performance explained the most, followed by HFPTA and then NU6 (see R^2 change [Δ] values under the model summary statistics section for each variable).

The beta weightings indicate that individuals with higher baseline WIN thresholds (i.e., poorer performance), better high-frequency hearing (lower HFPTAs), and better word-recognition abilities in quiet showed the most improvement on the WIN. Treatment arm was not retained as a predictor variable in the final model. In other words, the type of intervention did not affect outcome on the WIN.

Figure 1 displays the individual datum points of change scores as a function of each significant predictor variable (each in separate panels). Because treatment arm was not a significant predictor, all participants are plotted together. Figure 1A shows WIN change scores as a function of baseline WIN with a significant correlation between these two variables. The positive linear regression through the datum points illustrate the results from the multiple linear regression model that baseline WIN is a significant predictor of WIN outcome, and the correlation between these two variables was significant ($r = .334$, $p < .001$). HFPTA and NU6 scores also emerged as significant predictors in the multiple linear regression model; however, the amount of variance explained by these two predictor variables was small, and the correlation between them and the change scores was not significant. The flat linear regression lines through the datum points in Figures 1B and 1C speak to their limited clinical ability to predict outcome alone.

HHIA/E

The regression results are displayed in the middle section of Table 4. Three variables emerged as being significant predictors of HHIA/E outcome, including baseline HHIA/E score, age, and hearing aid user status, $F(3, 258) = 19.8$,

Table 2. The statistical descriptors for the change scores for each outcome variable as a function of treatment arm and overall.

Treatment arm	WIN (50% point dB S/N)				HHIA/E (points)				APHAP (%)			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max	*M*	*SD*	Min	Max
LACE-C	0.6	1.8	–3.2	9.2	2.1	18.7	–48.0	54.0	0.6	13.6	–29.9	27.9
LACE-DVD	0.8	1.3	–2.0	3.2	3.0	14.8	–30.0	44.0	1.0	12.3	–26.6	41.4
Placebo	0.8	1.4	–2.0	5.6	–0.5	10.8	–26.0	30.0	0.5	12.5	–31.3	39.1
Control	0.8	1.6	–4.4	4.8	3.9	14.1	–58.0	50.0	3.1	11.3	–26.5	25.1
All	0.8	1.5	–4.4	9.2	2.1	14.7	–58.0	54.0	1.3	12.4	–31.3	41.4

Note. WIN = Words-in-Noise test; S/N = signal-to-noise ratio; HHIA/E = Hearing Handicap Inventory for Adults/Elderly; APHAP = Abbreviated Profile of Hearing Aid Performance; LACE-C = Listening and Communication Enhancement–computerized; LACE-DVD = Listening and Communication Enhancement–DVD based.

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Table 3. The number and percentage of participants who had a positive or negative change score overall and whose scores exceeded the 95th percentile critical difference (CD) score for the primary measures.

	WIN		HHIA/E		APHAP	
Score	*n*	%	*n*	%	*n*	%
Positive change score	165	62.7	131	49.8	141	53.6
Exceeded CD score (+)	39	23.6	26	19.8	91	64.5
Negative change score	72	27.4	111	42.2	118	44.9
Exceeded CD score (–)	5	6.9	12	10.8	76	64.4
No change in score	26	9.9	21	8.0	4	1.5

Note. WIN = Words-in-Noise test; HHIA/E = Hearing Handicap Inventory for Adults/Elderly; APHAP = Abbreviated Profile of Hearing Aid Performance.

$p < .001$. Together, these variables explained a total of 18.7% of the variance. The beta weightings indicate, however, that listeners with poorer baseline HHIA/E scores (more hearing impairment), who are older, and who are new hearing aid users show more positive change scores on the HHIA/E. Of the variance explained, the majority was attributable to baseline HHIA/E score. The variance explained by age and hearing aid user status together was just 5%, and thus they would not likely be clinically meaningful predictors for identifying individuals who would show a positive change score on the HHIA/E. Once again, treatment arm was not retained in the final model, demonstrating again that the type of intervention had no impact on outcome.

As with the WIN, to illustrate better the contributions of these predictor variables to change scores on the HHIA/E, a graphical analysis was conducted. The individual datum points for HHIA/E change scores as a function of each predictor variable are displayed in separate panels in Figure 2. As with Figure 1, baseline performance (see Figure 2A) clearly is related to HHIA/E outcome ($r = .371$, $p < .001$), and the almost-flat regression line for Figure 2B (age) and the overlapping data for new and experienced hearing aid users in Figure 2C show these variables to be associated marginally with outcome. Figure 2C does, however, illustrate that there are a handful of new hearing aid users (circled in Figure 2C) that achieved larger improvements on the HHIA/E than any of the experienced hearing aid users. Thus, older new hearing aid users with poorer baseline HHIE results likely would be candidates for some postamplification rehabilitation.

APHAP

The regression model results are displayed in Table 4 (bottom portion) and showed that baseline APHAP and hearing aid user status predicted change on the APHAP, $F(2, 259) = 29.7$, $p < .001$. Together, these variables explained 18.7% of the variance. The largest contributor toward outcome was baseline APHAP, which explained 17.2% of the variance, and user status explained a meager 1.5%. Overall, these results suggest that higher baseline APHAP (poorer performance) yields greater positive change on the APHAP ($r = .419$, $p < .001$). Although significant, user status and, in particular, being a new user is not likely a clinically relevant predictor of change scores on the APHAP. As for the WIN and HHIA/E, these results are illustrated in Figure 3.

For this research forum article we focused on using predictor variables and outcome variables that would be

Table 4. The summary statistics from the multiple linear regression models conducted to identify variables that predicted short-term change on the three outcomes of interest.

	Coefficient				Model summary		
Measure	*b*	*SE*	β	*p*	*R*	$R^2\Delta$	*p*
WIN							
Baseline WIN	0.38	0.05	.60	< .001	.334	.112	< .001
HFPTA	–0.05	0.01	–.30	< .001	.445	.086	< .001
NU6	0.02	0.01	.17	.013	.466	.019	.013
HHIA/E							
Baseline HHIA/E	0.30	0.04	.43	< .001	.370	.137	< .001
Age	0.35	0.11	.18	.002	.409	.031	.002
User status	–4.12	1.67	–.14	.014	.432	.019	.014
APHAP							
Baseline APHAP	0.30	0.04	.44	< .001	.414	.172	< .001
User status	–3.01	1.39	–.12	.030	.432	.015	.030

Note. WIN = Words-in-Noise test; HFPTA = high-frequency pure-tone average; NU6 = Northwestern University Auditory Test Number 6; HHIA/E = Hearing Handicap Inventory for Adults/Elderly; APHAP = Abbreviated Profile of Hearing Aid Performance.

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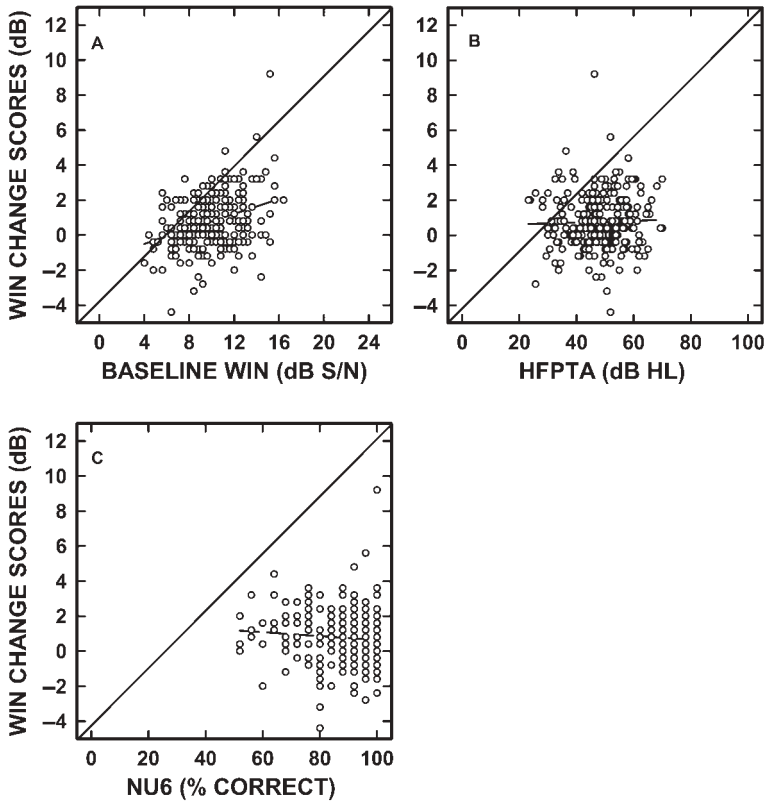
Figure 1. The individual datum points for change scores on the Words-in-Noise test (WIN) are plotted as a function of baseline WIN performance (dB signal to noise [S/N]) in Panel A, unaided bilateral high-frequency pure-tone average (HFPTA in dB HL) in Panel B, and unaided bilateral word-recognition scores in quiet (percentage correct) on the Northwestern University Test Number 6 (NU6) in Panel C. The solid line in each panel represents the line of equality, and the dashed line represents the linear regression through the datum points.



readily available to a clinician, many of which are obtained routinely and others that could be obtained easily. The interested reader, however, is referred to the online supplemental materials (see Supplemental Table 1) for regression results on the other experimental/research outcome variables from the RCT. For details about the measures themselves, see Saunders et al. (2016).

Discussion

We sought to examine individual data from a multisite RCT of bilateral hearing aid users that compared formal (LACE-C, LACE-DVD) and informal (placebo) AT with a control condition in order to determine if patient and/or clinical variables exist that could predict who would benefit from supplemental AT. Although several predictor variables remained as predictors in the models derived, when the amount of variance accounted for by each predictor variable was considered only the baseline performance on each outcome measure was meaningfully predictive. To be specific, baseline performance on each measure explained between 11.7% and 17.2% of the variance in change scores on that measure, and other predictor variables, although they emerged as significant, explained less than 9% of the variance, with all but HFPTA explaining less than 4% of the variance. Thus, these variables (e.g., NU6 scores, HFPTA, user status, age, etc.) would not individually and independently facilitate clinical decisions as to who might be a candidate for postamplification AT but, taken together with baseline performance, they may enhance the clinical decision. It also should be noted that all participants had high motivation (>9.0 on average) for participating in AT. Because of the restricted range in scores, motivation may not have emerged as a significant predictor variable in the current models and sample.

Treatment arm did not enter the regression model for any of the outcome measures; thus, it must be concluded that the informal and formal AT programs were no more effective at improving outcomes in these hearing aid users than was the 30-min educational counseling session provided to the control group. This is perhaps not surprising in light of the fact that analyses of our data at the group level failed to demonstrate robust treatment effects of AT on any of the outcome measures used in the clinical trial (Saunders et al., 2016).

Our finding that baseline performance predicts outcome is not unique. Many other studies of AT have reported similar results regarding baseline performance

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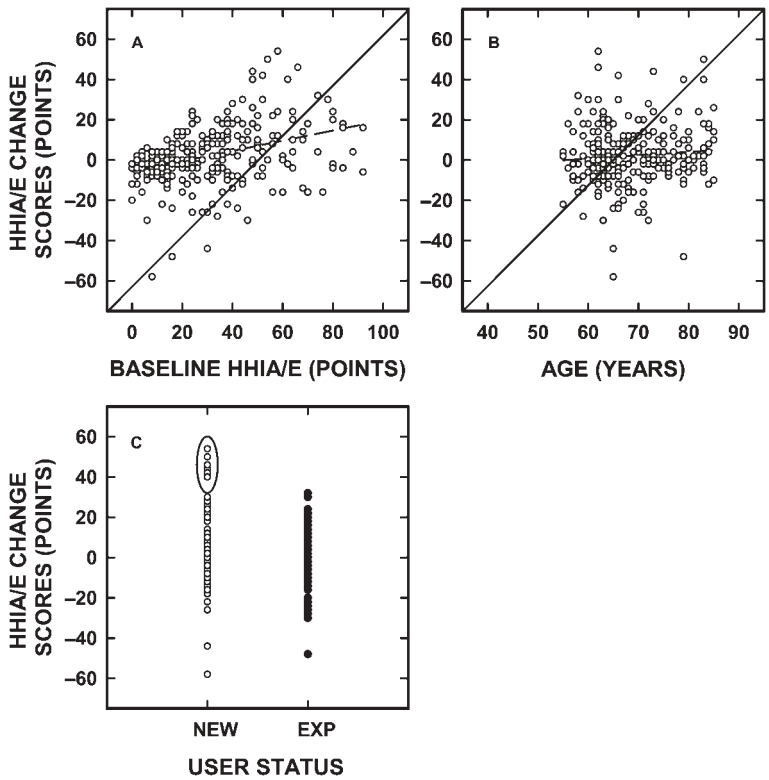
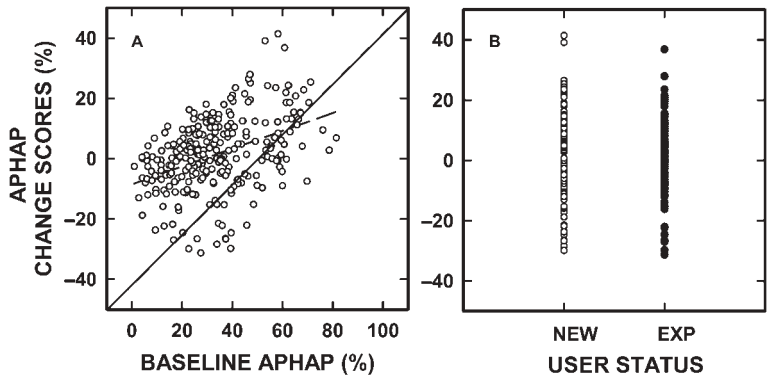
Figure 2. The individual datum points for change scores on the Hearing Handicap Inventory for Adults/Elderly (HHIA/E) are plotted as a function of baseline HHIA/E performance (in points) in Panel A, age (in years) in Panel B, and user status (categorized by new vs. experienced [Exp]) in Panel C. The solid line in Panels A and B represents the line of equality, and the dashed line represents the linear regression through the datum points.



(e.g., Abrams & Chisolm, 2013; Dubno, 2013; Humes et al., 2009; Kricos & Holmes, 1996; Stecker et al., 2006; Sweetow & Sabes, 2006; Walden et al., 1981). To elaborate on some of these findings, Humes et al. (2009) showed that baseline performance on a sentence recognition task explained 43.5% of the variance in training (frequent word AT) benefit on that task. Kricos and Holmes (1996) showed that the pretraining scores of individuals with poorer auditory–visual speech-in-noise abilities improved the most on that task. They found a similar result with a

Figure 3. The individual datum points for change scores on the Abbreviated Profile of Hearing Aid Performance (APHAP) are plotted as a function of baseline APHAP performance (in percentage) in Panel A and user status (new vs. experienced [Exp]) in Panel B. The solid line in Panel A represents the line of equality, and the dashed line represents the linear regression through the datum points.



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self-report measure. Last, Walden et al. (1981) demonstrated that participants with the poorest baseline consonant and sentence recognition benefited the most from an analytic AT program.

Unlike the current study, however, most previous studies did not have a no-AT control group; that is, although our data show that participants with the poorest baseline scores showed the greatest improvement, the finding that treatment arm was not a significant predictor of outcome implies that the association between baseline performance and outcome was not mediated by formal or informal AT. As noted by Saunders et al. (2016), this suggests that changes in performance might be associated with learning/practice effects of testing rather than effects of the interventions themselves. This hypothesis is supported further by the data in Table 2 showing that the mean change scores were negligible and, as noted above, few participants showed positive changes that exceeded the 95% CD scores on any measure. Similar observations were noted by Sabin, Clark, Eddins, and Wright (2013), who showed that a no-training control group of listeners improved as much as a training group on a spectral modulation detection task. Amitay, Irwin, and Moore (2006) found similar results in their study and suggested that simply participating in a task can lead to performance improvements on that task. Thus, individuals in the current study with poorer baseline performance may have improved on outcomes merely by engaging in testing.

In a clinical setting, then, an individual's performance on subjective and behavioral measures prior to receiving supplemental AT and/or educational counseling in conjunction with hearing aid use is the best predictor of outcome. Individuals who have residual aided hearing difficulties thus may be candidates for some type of supplemental audiologic rehabilitation. Because this finding holds for both self-report and behavioral measures, assessment of subjective and/or behavioral performance provides valuable information for clinical decision making. The data also show, however, that no one intervention examined here (LACE-C, LACE-DVD, placebo, control) was more effective than another because there was not an effect of treatment arm. Thus, it is not appropriate to recommend formal AT in the form of LACE over and above an educational program (control) or any type of active listening (placebo). It should be noted, however, that the participants in this study who completed the LACE-C program in its entirety (i.e., all 20 training sessions) had better outcomes on four out of seven outcomes relative to those who did not complete all training sessions (Chisolm et al., 2013). Thus, in relation to formal computer-based LACE training, any recommendation for use by a patient should stress that the maximum benefit is most likely to be achieved when individuals are compliant with the entire treatment protocol. Because compliance data for all treatment arms in the RCT were not fully available, the role of compliance in individual benefit from AT warrants further examination. It also should be noted that the RCT evaluated AT only in the form of LACE, and thus the results and recommendations made on the basis of the RCT may not be generalizable to other AT approaches or programs.

In conclusion, in an effort to identify candidates for AT we examined whether several variables that easily are obtainable during routine clinical visits were predictors of speech-in-noise or self-report outcomes in new and experienced hearing aid users who were provided with supplemental AT (formal AT, informal AT) or a short educational session (control). The overarching conclusion was that only baseline performances reflecting residual hearing difficulties predicted change scores on the outcomes assessed, such that those with poorer baseline scores showed greater gains. These gains, however, were not specific to a given intervention type assessed in the RCT. In particular, the data from this RCT do not support the recommendation of LACE-C or LACE-DVD training over a book-on-tape training (placebo) or an educational session (control) but instead suggest that any of these interventions may help hearing aid users achieve better outcomes. Thus, hearing aid users who present with residual speech-in-noise difficulties, activity limitations, participation restrictions, and/or aided listening difficulties should be considered candidates for supplemental audiologic rehabilitation regardless of the type.

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