A Naturalistic Approach to Assessing Hearing Aid Candidacy and Motivating Hearing Aid Use

DOI: 10.3766/jaaa.20.10.3

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Abstract

Background: Although the benefits of amplification for persons with impaired hearing are well established, many potential candidates do not obtain and use hearing aids. In some cases, this is because the individual is not convinced that amplification will be of sufficient benefit in those everyday listening situations where he or she is experiencing difficulties.

Purpose: To describe the development of a naturalistic approach to assessing hearing aid candidacy and motivating hearing aid use based on patient preferences for unamplified and amplified sound samples typical of those encountered in everyday living and to assess the validity of these preference ratings to predict hearing aid candidacy.

Research Design: Prospective experimental study comparing preference ratings for unamplified and amplified sound samples of patients with a clinical recommendation for hearing aid use and patients for whom amplification was not prescribed.

Study Sample: Forty-eight adults self-referred to the Army Audiology and Speech Center for a hearing evaluation.

Data Collection and Analysis: Unamplified and amplified sound samples were presented to potential hearing aid candidates using a three-alternative forced-choice paradigm. Participants were free to switch at will among the three processing options (no gain, mild gain, moderate gain) until the preferred option was determined. Following this task, each participant was seen for a diagnostic hearing evaluation by one of eight staff audiologists with no knowledge of the preference data. Patient preferences for the three processing options were used to predict the attending audiologists' recommendations for amplification based on traditional audiometric measures.

Results: Hearing aid candidacy was predicted with moderate accuracy from the patients' preferences for amplified sounds typical of those encountered in everyday living, although the predictive validity of the various sound samples varied widely.

Conclusions: Preferences for amplified sounds were generally predictive of hearing aid candidacy. However, the predictive validity of the preference ratings was not sufficient to replace traditional clinical determinations of hearing aid candidacy in individual patients. Because the sound samples are common to patients' everyday listening experiences, they provide a quick and intuitive method of demonstrating the potential benefit of amplification to patients who might otherwise not accept a prescription for hearing aids.

Key Words: Candidacy, everyday listening, hearing aids

Abbreviations: AASC = Army Audiology and Speech Center; ELA = Everyday Listening Assessment; KEMAR = Knowles Electronics Manikin for Acoustic Research; SNR = signal-to-noise ratio; WDRC = wide-dynamic range compression

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Parts of the work reported here were presented at AudiologyNOW! 2005, Washington, DC.

This research received support from Etymötic Research, Inc., Elk Grove Village, Illinois, through a Cooperative Research and Development Agreement with the Clinical Investigation Regulatory Office, U.S. Army Medical Department, Ft. Sam Houston, Texas.

It is well established that hearing aids provide benefit and improved quality of life to persons with impaired hearing (Larson et al, 2000; Chisolm et al, 2007). Nevertheless, only a fraction of persons with impaired hearing who could benefit from amplification actually obtain and use hearing aids. Kochkin (2005) reports MarkeTrak data from 1989–2004 that reveal a steady increase in the incidence of hearing loss among the general population. However, despite advances in hearing aid technology, the percentage of persons with impaired hearing who actually obtain and use hearing aids remained below 25 percent throughout this period.

There are many possible explanations for why hearing aid use has not increased, including cost, the stigma associated with hearing aid use, and the limitations of amplification to remediate the fundamental difficulty of understanding speech in background noise that is encountered by persons with impaired hearing in everyday living. Kochkin (2007) assesses numerous possible obstacles to use of hearing aids and concludes that patient recognition and acceptance of the communication problems caused by their hearing loss and the benefit that is available from hearing aid use are important prerequisites to hearing aid acceptance. When these prerequisites are considered in relationship to why patients often seek help for hearing impairment, some insight into the relatively limited use of hearing aids among persons with impaired hearing may be possible. Often patients are referred for hearing aid evaluation by another health care professional. Further, many self-referrals are actually motivated by the frustration of the spouse or of other significant persons communicating with the patient, rather than perceived need on the part of the patient. It is also the case that, for the majority of patients—those with mild to moderate hearing impairments—only intermittent hearing problems are encountered in daily living. Often patients will report difficulties limited to certain listening environments and/or talkers. Notably, the audiometric test booth and the audiologist's voice often are not problematic. The typical clinical encounter, therefore, may do little to convince the patient of the need for hearing aids.

Nevertheless, the essential first ingredient in a successful hearing aid fitting is the patient's belief that he or she can benefit from amplification. Unfortunately, it appears that the majority of nonusers who suspect they have a hearing loss do not believe that hearing aids will help them (Kricos et al, 1991). It is a common clinical experience that patients being evaluated for hearing aids will not admit a need but, rather, ascribe the source of their problems to the communication behavior of others. Further, many patients are pessimistic that hearing aids will benefit them sufficiently to offset their negative attitude toward hearing aid use. In contrast, patients who recognize their communication difficulties and are optimistic that hearing aids can help tend to be more successful. For example, Cox and Alexander (2000) observed a significant positive correlation between prefitting expectations and postfitting satisfaction. Similarly, Jerram and Purdy (2001) report that greater use of hearing aids was associated with greater acceptance of hearing loss and higher prefitting expectations. In summary, although several published studies identify the characteristics of patients who are more likely to accept hearing aid use (Cox et al, 2005; Kochkin, 2007; Meister et al, 2008), to our knowledge none has described a systematic clinical intervention designed to increase nonusers' expectations and motivation for hearing aid use.

Both clinical research and experience suggest that getting patients to accept hearing aid use appears to depend upon increasing their acceptance that communication problems exist across a range of listening situations that are relevant to their daily living and creating optimism that hearing aids can help in those situations. This article describes the development of a self-administered listening task designed to address these issues. Specifically, the Everyday Listening Assessment (ELA) was constructed, consisting of sound samples simulating a wide range of everyday listening situations presented at realistic (unaided) presentation levels and through two conditions of amplification. Patients indicate their preferences for unamplified and amplified versions of these stimuli. In the clinic, ELA preference ratings are used primarily as a counseling tool to encourage hearing aid use. To validate the task for this purpose, ELA preference ratings were related to hearing aid candidacy as determined by standard of care measures.

METHOD

Development of the Listening Task

The first step in the development of the ELA was to identify everyday listening situations that are frequently problematic for persons with impaired hearing. A heuristic approach was adopted, using a panel of four audiologists from the Audiology Section of the Army Audiology and Speech Center (AASC), each with more than 15 years of clinical experience. Working as a group, they were asked to create a list of everyday listening situations that are frequently reported to be difficult by patients seeking an evaluation of their hearing who do not wear hearing aids. Initially, a list of more than 40 such listening situations was generated. Next, the panel was asked to form a consensus list of the most frequently reported difficult listening situations from their initial lists, combining and modifying items as appropriate. Table 1 summarizes the 14 everyday listening situations that emerged from this process. Although this compilation of problematic listening situations was specifically generated to be

Table 1. Everyday Listening Situations That Are Most Frequently Reported to Be Problematic by Patients Who Are Nonusers of Hearing Aids and Are Seeking an Evaluation of Their Hearing

- Listening to child in quiet
- Conversation with TV in background
- Talking in a restaurant
- Listening in large theater or sanctuary
- Listening in conference room or classroom
- At the movies
- Conversation at cocktail party
- Conversation in car with radio playing in background
- Dinner conversation
- Listening to child at play outdoors
- Conversation with someone in another room
- Listening to vocal music
- Listening to instrumental music
- Hearing the sounds of nature

representative of the adult patient population of the AASC, it is generally consistent with categorical summaries of everyday listening situations previously reported in the literature (Walden et al, 1984; Cox and Gilmore, 1990; Kuk, 1992; Gatehouse, 1999).

The next step in the development of the ELA was to characterize each of the 14 everyday listening situations acoustically. The goal was to create representations of these listening situations in which the composite sound samples had known acoustic characteristics. The first step in this process was accomplished by a panel of four hearing scientists from the Research Section of the AASC. Each of the 14 everyday listening situations was described categorically by the panel in terms of five characteristics of sounds encountered in everyday living: signal source, signal input level, background noise, signal-to-noise ratio (SNR), and amount of reverberation. Specific values of each of these five characteristics were assigned to be representative of typical speech and noise levels for various listening environments (Pearsons et al, 1976; Plomp, 1977; Teder, 1990), as well as to represent a range of values for each characteristic across the 14 listening situations. The results are summarized in Table 2. Thus, for example, the first target listening environment ("listening to child in quiet") was characterized as a female child talking at 65 dB SPL without background noise or noticeable reverberation. Similarly, the third target environment ("conversation in a restaurant") was characterized as an adult female talking at 72 dB SPL, with competing six-talker babble at a +5 dB SNR and moderate reverberation. In many cases, the specific characteristics selected by the panel were somewhat arbitrary in order to utilize a relatively equal distribution of the subcategories of the five characteristics across the 14 everyday listening situations. This was especially true for choosing a male or female talker and, to a lesser extent, selecting the SNR, presentation level, and conditions of reverberation.

Production of Composite Sound Samples

Composite representations of the 14 everyday listening situations were created by mixing digital recordings of speech, music, sounds of nature, and background noises, at the presentation levels, SNRs, and reverberation conditions specified in Table 2. The duration of the composite sound samples varied from 15 sec (bird vocalizations) to 71 sec (orchestra). Male, female, adult, and child talkers were recorded in an audiometric test booth reading a variety of narrative texts. Recordings of various environmental sounds/noises were obtained from the Internet, including traffic noise, machine noise, speech-shaped noise, playground noises, and sounds of nature (e.g., bird vocalizations). Music samples were taken from available recordings.

Production of each of the 14 composite sound samples began by setting the level of the target signal (e.g., speech, music, environmental sounds) relative to a continuous speech-shaped noise, nominally set to an overall root mean square level of 80 dB SPL, to achieve the (relative) signal input levels specified in Table 2. Next, background noise was mixed at the prescribed SNR. Finally, reverberation was digitally applied (Elhilali et al, 2003) to the mixed SNR recordings.

In addition to the 14 composite sound samples described above, seven additional samples were included in the listening task. Unlike the 14 composite samples, these supplemental samples received no additional signal processing (i.e., background noise, reverberation) beyond that which existed in the recording environment. Four were studio recordings of music that varied in genre and relative level (in parentheses), including instrumental rock (75 dB SPL), vocal rock (88 dB SPL), vocal country (80 dB SPL), and a classical two-violin concerto (65 dB SPL). The remaining three samples were listening situations with speech as the signal of interest. Two were soundfield recordings made in a typical living room by a single microphone positioned approximately 5 ft in front of the television loudspeaker and included samples of a male baseball play-by-play announcer (70 dB SPL) and a male television news announcer (60 dB SPL), respectively. The other sample from a soundfield recording was of a male talker in a noisy cafeteria (74 dB SPL, average +5 SNR). The (relative) presentation levels of these seven supplemental sound samples were assigned arbitrarily to be representative of similar sounds occurring in everyday listening, as well as to achieve a range and balance of presentation levels across the 21 samples. Other specific characteristics of these samples (e.g., background noise, SNR, reverberation) were uncontrolled, reflecting the acoustic environment in which these recordings were made.

Table 2. Characteristics of Composite Sound Samples

	VOICE			SNR					Relative Level							Background Noise						Reverberation	
Target Environ	Child	Female	Male	Quiet	+10	+8	+5	0	50	55	60	65	72	75	80	6Talker	2Talker	Machine	Playground	Traffic	Music	Mod	High
1. Child in quiet	X	X		X								X											
2. TV in background		X			X							X					X						
3. Restaurant		X					X						X			X						X	
4. Large theatre/sanc			X		X							X					X						X
5. Conf room/classrm			X		X							X						X				X	
6. At the movies		X			X									X				X				X	
7. Cocktail party		X						X						X		X							
8. Car with radio			X				X					X								X	X		
9. Dinner conversation		X		X								X										X	
10. Child on playground	X		X				X			X									X				
11. Talker in other room		X		X					X														
12. Music—lounge singer			X			X									X	X						X	
13. Music—orchestral				X										X									X
14. Bird mix											X												

Hearing Aid Processing

Recall that the ELA consists of sound samples presented unaided and under two conditions of amplification. The hearing aid–processed recordings were made in the 8 ft cube (interior space) anechoic chamber of Etymötic Research (Elk Grove, Illinois). The 21 sound samples were presented through an Advent Model V570 loudspeaker to a single-channel wide-dynamic range compression (WDRC [K-Amp^{TM}]) hearing aid affixed to the right ear of the Knowles Electronics Manikin for Acoustic Research (KEMAR [Burkhard and Sachs, 1975]). The hearing aid used to signal process the sound samples was selected because of its basic amplification features. Specifically, gain, frequency response, and compression could be manipulated within a single channel. The same hearing aid processing was used for all participants; that is, no attempt was made to fit the amplification parameters for the two gain conditions to the participants' hearing losses.

The speech-shaped calibration noise was used to calibrate the presentation levels of the digital sound samples. Using the built-in amplifier in the loudspeaker, the level of the calibration noise at the hearing aid microphone was adjusted to 80 dB SPL as read on a sound level meter. The composite sound samples were then played without changing the gain of the amplifier for each of three signal-processing conditions through KEMAR using an Etymötic ER-11 microphone attached to a Zwislocki coupler. The output of the microphone was digitally recorded for each of the signal-processing conditions: no hearing aid ("no gain" condition, i.e., only the effects of the microphone and recording equipment), the hearing aid set to mild gain, and the hearing aid set to moderate gain. The gain/frequency responses for the mild and moderate gain conditions for three input levels are shown in Figure 1. The specific amplification parameters of the two hearing aid gain conditions were selected as generic fittings appropriate to first-time hearing aid candidates typically encountered in our clinic, that is, patients with mild to moderate predominately high-frequency hearing loss.

Presentation of Sound Samples

Sound samples were stored on a Dell Optiplex GX240 PC, D/A converted (16 bit D/A, 44,100 Hz sampling rate), and presented monaurally over Sennheiser HD580 headphones. The digital sound samples were scaled by a fixed value in order to set the output level of the headphones to 80 dB SPL for the calibration signal. The level of the calibration signal was verified using a Larsen-Davis AEC101 flat-plate coupler and a Larsen-Davis 800B sound level meter.

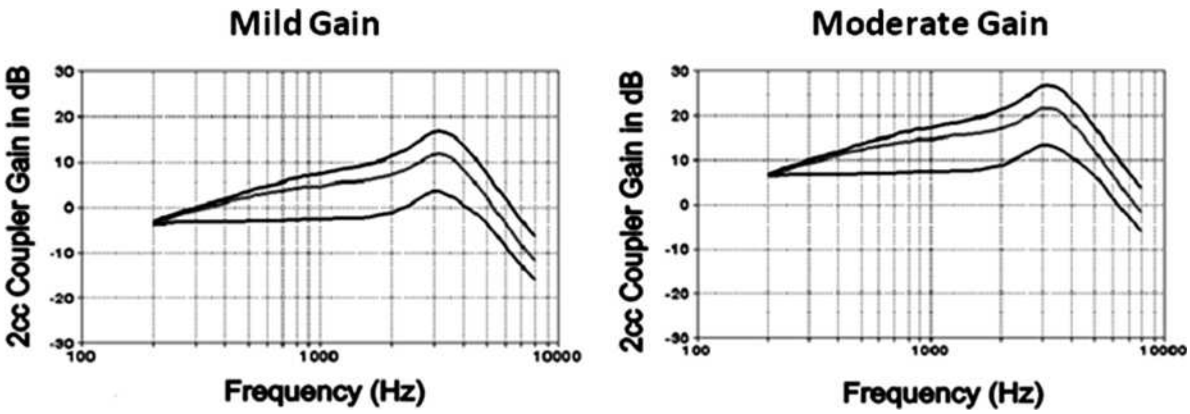

Figure 1. Coupler gain response (2 cc) for inputs of 50 dB SPL (highest curve), 70 dB SPL (middle), and 90 dB SPL (lowest curve) for the mild gain and moderate gain recording conditions.

The ELA listening task consists of the 21 everyday sound samples presented separately to each ear, resulting in a total of 42 items. The task is administered under computer control, using a touch screen to capture patient responses. Informal pilot studies of earlier versions of the ELA kiosk were conducted to make sure that adult patients representing a wide range of ages, cognitive skills, reading ability, and visual acuity were able to understand the instructions and perform the task appropriately. As a result of this pilot work, earlier versions of the instructions and ELA screens were modified. During the actual validation study, the kiosk presentation included an interview question immediately following the ELA preference rating task: "Prior to listening to the recordings, you were provided instructions on the computer screen. Push the button which best describes your understanding of those instructions." Three response choices were included on the screen: (1) "The instructions were very clear. I had no trouble understanding what I was supposed to do"; (2) "The instructions were generally clear, although I would have liked to ask a question to clarify what I was supposed to do"; (3) "I was confused by the instructions. I was not sure what I was supposed to do." Of the 46 participants who responded to this screen, 45 indicated that the instructions were clear and they had no difficulty understanding what they were supposed to do. The other participant indicated that the instructions were generally clear. Additionally, one patient who was initially enrolled in the study reported some difficulty reading the kiosk screens due to print size that was too small for this person to read comfortably. Consequently, that individual was dismissed from the study.

Figure 2 shows the screen for one of the items (i.e., Sample 9, dinner conversation: female talker in quiet, presented to the left ear). The order of presentation of the 42 items is determined randomly by the computer. For each item, the three processing modes (no gain, mild gain, moderate gain) are randomly assigned by the computer to the three Play Option buttons on the touch screen. The patient initiates each item (sound sample) by touching one of the three Play Option buttons. Presentation of each processing mode recording is interrupted by pressing one of the other two Play Option buttons. For each item, each processing option must be selected and played at least briefly. There are no restrictions on the order or number of times that the patient can listen to each option before deciding which is preferred. When the patient changes options, the sound sample resumes under the new option at the same point in the sound sample. No specific guidance is provided regarding how preference should be determined. Patient preferences among the three processing options are indicated using the second set of buttons on the touch screen. If the overall duration of the sound sample is exceeded before the patient selects a preference, the sample automatically loops to the beginning of the sound sample without interruption.

Validation of the Listening Task

Recall that the ELA was designed to motivate patients to accept a hearing aid prescription who might otherwise be uncertain regarding their hearing aid candidacy. For the purposes of this study, candidacy was defined as the attending audiologist's decision to prescribe amplification for a patient. Although it seems intuitive that patient preferences for amplified sound would bear a predictive relationship with clinical decisions regarding candidacy, there are multiple considerations that factor into such determinations, such as patient needs, expectations, lifestyle, dexterity, cognitive abilities, and cost considerations. Consequently, the validity of the ELA to predict hearing aid candidacy was assessed by obtaining ELA responses from patients being seen in the clinic for a hearing evaluation and comparing those results to clinical decisions regarding hearing aid candidacy based on standard of care criteria—that is,

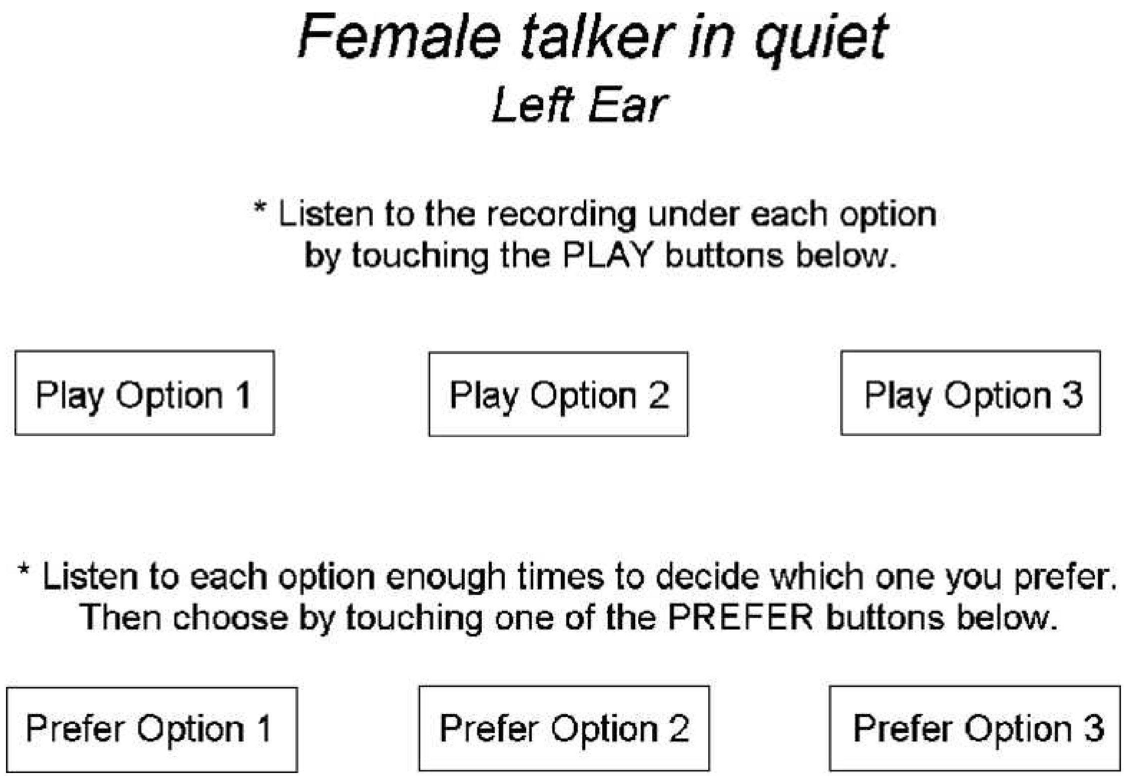

Figure 2. Touch screen display for one of the 42 items in the listening task.

based on the individual clinician's best judgment, including all considerations that factor into prescribing amplification for a given patient. Obviously, if ELA ratings are only minimally related to such clinical determinations of candidacy, use of those ratings to motivate hearing aid use would be unjustified.

Participants

Forty-eight adults, self-referred for hearing evaluations, participated in the validation study. Participants were 26–85 years of age (M = 60.6, SD = 16.4) and included 42 males and 6 females. A wide range of hearing was represented in the sample, including participants with normal hearing and participants with relatively severe hearing loss. None of the participants was wearing hearing aids or had worn hearing aids previously at the time of participation.

Recruitment and Procedures

When self-referred patients with no hearing aid experience reported for their clinic appointments, they were given a printed sheet by the receptionist that briefly described the listening task and asked whether they were willing to participate. Those who indicated willingness were referred to the first author, who obtained informed consent. The participants were then taken to the waiting area in the hearing aid repair/earmold laboratory of the AASC where the ELA kiosk is located. Because all of the sound samples are presented suprathreshold, a sound-treated environment is not required. A desk and chair were set up in one corner of this space to conduct the listening task. The ELA is designed to be self-administered, that is, it does not require instruction or intervention by the audiologist. The default (opening) screen instructed the participant to put on the earphones, which were clearly marked left and right, and to watch the computer screen. A series of instructional screens informed the participant how to take the listening task. The ELA is self-paced, and participants typically took 15–20 min to complete it. The last screen instructed the participants to return to the main clinic waiting room for their regularly scheduled audiology appointments.

Following participation in the listening task, each participant was seen by one of eight staff audiologists for a diagnostic hearing evaluation. The attending audiologists were aware that the patients were participating in a research study that involved listening to and rating samples of speech. However, they did not know its full purpose, nor did they have access to any patient's ELA results. The tests administered during the hearing evaluation were at the discretion of the audiologist based on patient needs but typically included air- and bone-conduction thresholds, speech reception thresholds, word recognition in quiet, and

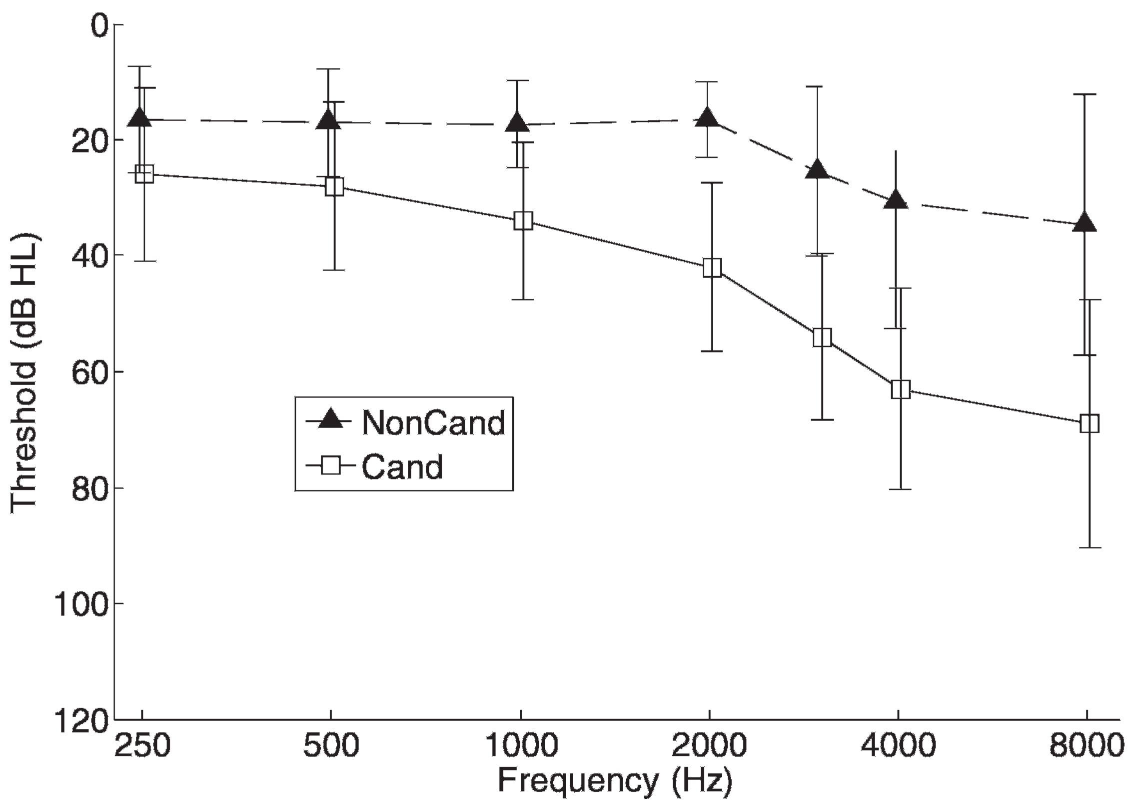

Figure 3. Mean audiograms for the hearing aid candidate ("Cand," n = 46) and noncandidate ("NonCand," n = 50) ears. Error bars indicate one standard deviation.

immittance. For many patients, especially those for whom a prescription for amplification was being considered, speech-recognition ability in background noise was also assessed. At the conclusion of the hearing evaluation, the attending audiologist determined the need for hearing aid treatment based on his or her own clinical judgment. This recommendation was recorded in the patient's file, which was later reviewed by the first author.

RESULTS AND DISCUSSION

Based on the standard hearing evaluations, amplification was not prescribed in either ear for 22 of the participants; bilateral hearing aids were prescribed for 20 participants, and unilateral amplification was prescribed for an additional 6 participants. Unilateral prescriptions were made for four participants with unilateral hearing loss, that is, normal or near-normal hearing in one ear. The other two participants for whom unilateral prescriptions were made had asymmetric hearing loss, with a mild loss in the better ear but a greater degree of loss in the ear for which amplification was prescribed. Hence, hearing aids were prescribed for 46 of 96 ears. Mean audiograms for the 46 candidate ears for which hearing aids were prescribed and the 50 noncandidate ears for which hearing aids were not prescribed are shown in Figure 3.

Figures 4–6 show the ELA results for three illustrative participants receiving different hearing aid recommendations from the attending audiologist. Figure 4 shows the processing preferences and audiogram of a participant for whom hearing aids were not prescribed for either ear. Not surprisingly, the participant's audiogram reveals thresholds within normal limits bilaterally. Preference ratings tended to be either no gain or mild gain for all sound samples except those with the softest presentation levels. Figure 5 summarizes the data of a participant for whom amplification was prescribed in the left ear but not for the right ear. The audiogram shows thresholds within normal limits in the right ear (for which amplification was not prescribed) and a mild reduction in threshold sensitivity in the left ear. Despite having only a mild unilateral loss, this participant complained of difficulty communicating in several specific listening situations, including business meetings. With few exceptions, this participant preferred unaided (no gain) processing in the right ear and moderate gain processing in the left ear. Finally, Figure 6 shows results for a participant for whom hearing aids were prescribed bilaterally. This participant had a mild to moderate hearing loss in both ears. Processing preferences tended to depend upon the presentation level of the primary signal in the sound sample, with moderate gain preferred for signals at 65 dB SPL and below and mild gain preferred for signals above this level.

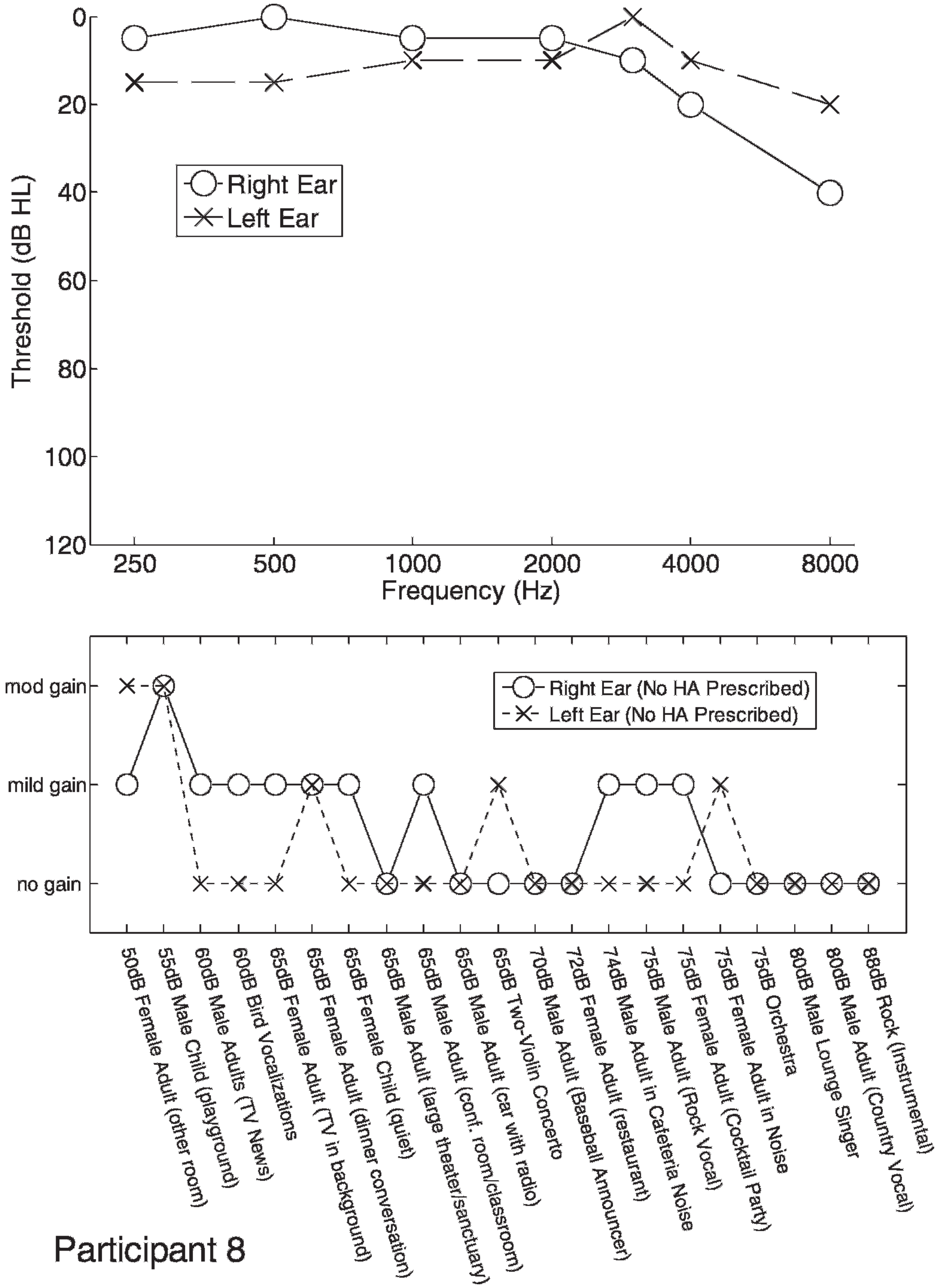

Figure 4. Audiogram and signal processing preferences for each sound sample in each ear of a participant for whom hearing aids were not prescribed in either ear. The 21 sound samples are arranged along the abscissa according to the presentation level of the primary signal.

Validation Study

The results of the validation study consisted of preferences for unaided, mild gain, and moderate gain processing of 21 listening scenarios presented separately to each ear of 48 patients self-referred for a hearing evaluation. ELA preferences were analyzed according to the attending audiologists' recommendations regarding amplification in each ear. Preferences for no gain, mild gain, and moderate gain were assigned numerical ratings of 1, 2, and 3, respectively. Mean preference ratings for each of the 21 sound samples are shown according to hearing aid recommendation in Figure 7. The 21 listening scenarios are arranged along the abscissa according to increasing (unaided) presentation level of the primary signal. The three samples consisting of soundfield recordings in actual everyday listening environments are noted by a

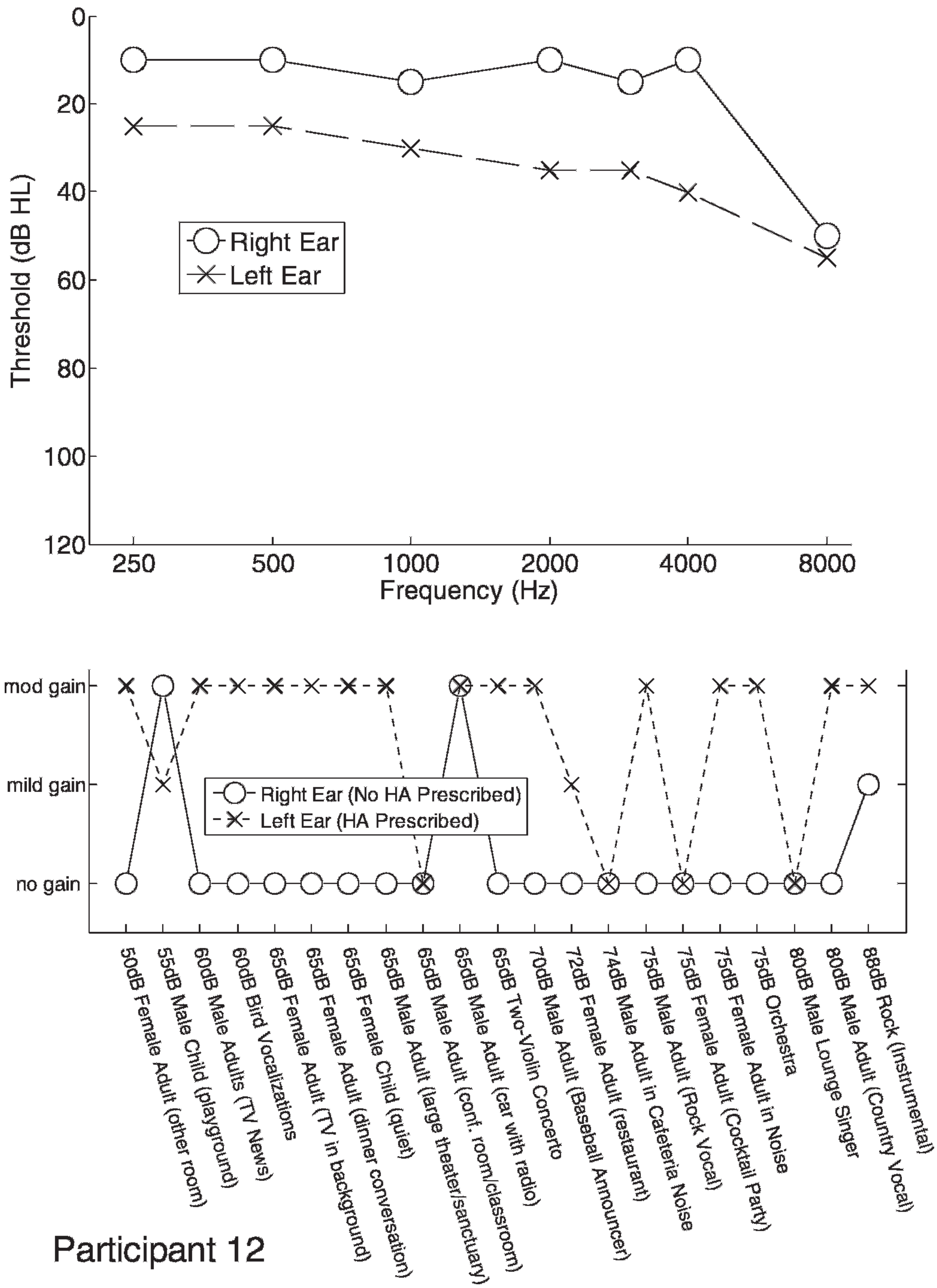

Figure 5. Audiogram and signal processing preferences for each sound sample in each ear of a participant for whom a hearing aid was prescribed in the left ear but not in the right ear.

single asterisk, and the four samples taken from commercially available musical recordings are indicated by two asterisks. Results for the seven supplemental sound samples appear similar to those of the 14 simulated sound samples, and, therefore, no further distinction will be made between these items.

Notably, on average, some preference for amplification was observed for every sound sample for both the candidate and noncandidate ears, although this tended to vary with the unaided presentation level. As might be expected, the general trend was toward less preference for amplification as the unaided presentation level increased. These results suggest that persons with normal or near-normal hearing sometimes prefer slightly louder levels than naturally occur in everyday listening environments, suggesting that preferences of mild gain for relatively soft environmental sounds may not be a good predictor of hearing aid candidacy.

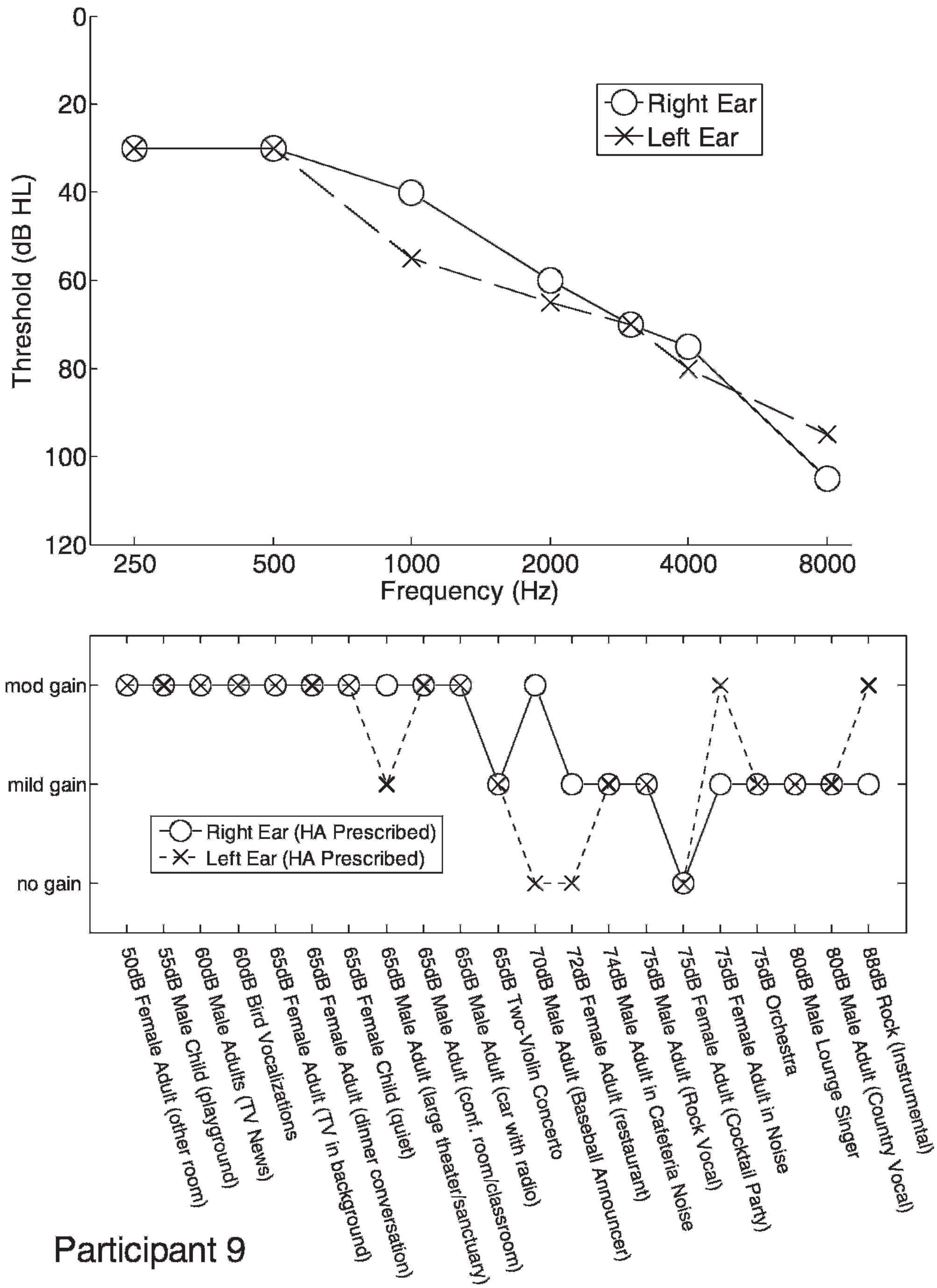

Figure 6. Audiogram and signal processing preferences for each sound sample in each ear of a participant for whom hearing aids were recommended bilaterally.

In any case, it is clear that the mean ratings for all 21 sound samples differed between the candidate and noncandidate ears, although the distinction varied considerably across the sound samples. This is seen more clearly in Figure 8, which shows the difference between the mean preference rating of the candidate and noncandidate ears for each of the sound samples arranged according to the magnitude of this difference. Assuming that the more widely separated the mean ratings of the candidate and noncandidate ears, the better the sound sample was at predicting the audiologists' recommendations regarding amplification, several of the sound samples appeared minimally useful as predictors.

One of the sound samples (75 dB Orchestra) was distinctly superior to the others in discriminating between the candidate and noncandidate ears. This item was followed by six additional samples that also yielded a substantial difference between the two candidate categories and, therefore, appeared to offer

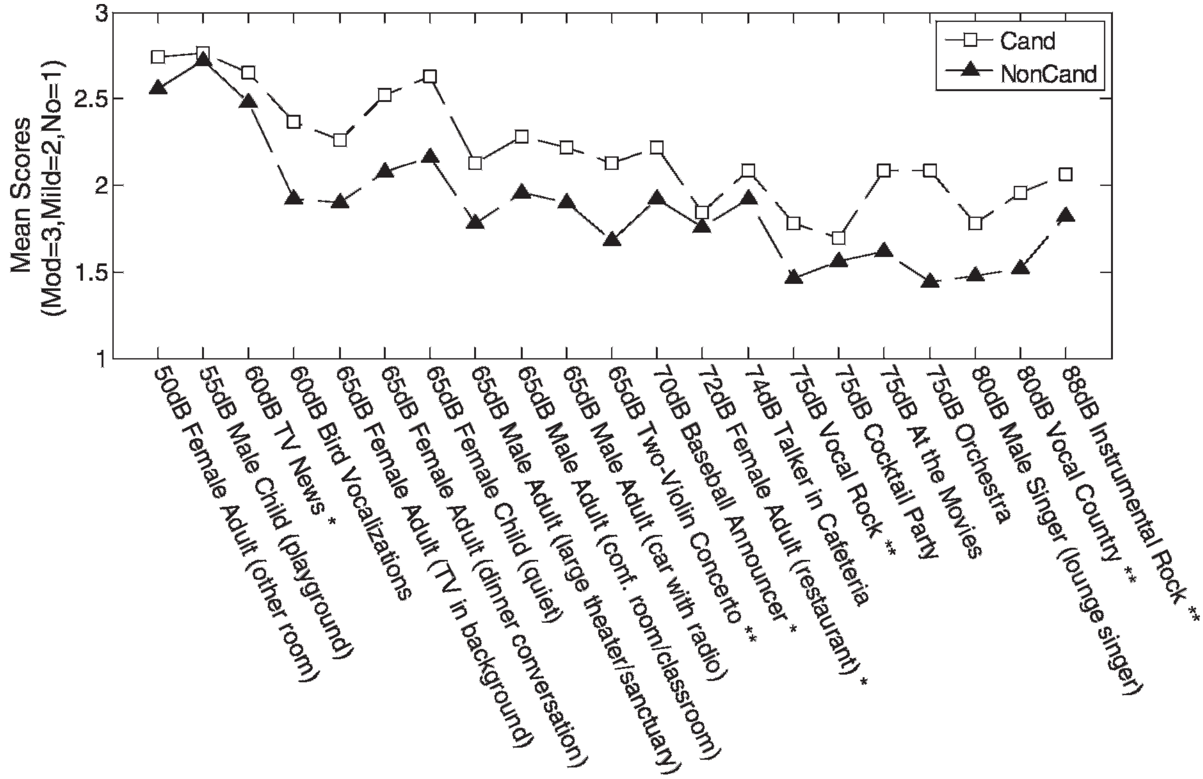

Figure 7. Mean preference rating for each sound sample according to hearing aid recommendation (candidate vs noncandidate). The three samples consisting of soundfield recordings in actual everyday listening environments are noted by a single asterisk, and the four samples taken from commercially available musical recordings are indicated by two asterisks.

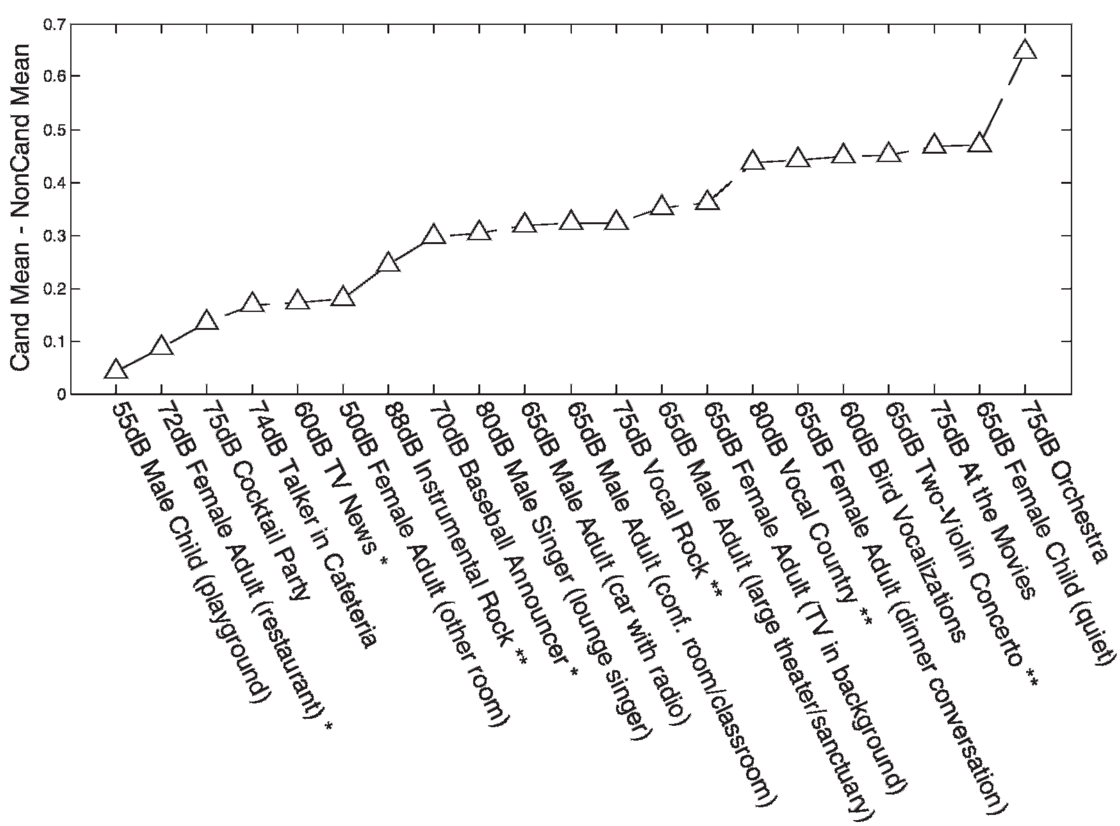

Figure 8. Difference between mean preference ratings in the candidate and noncandidate ears for each sound sample.

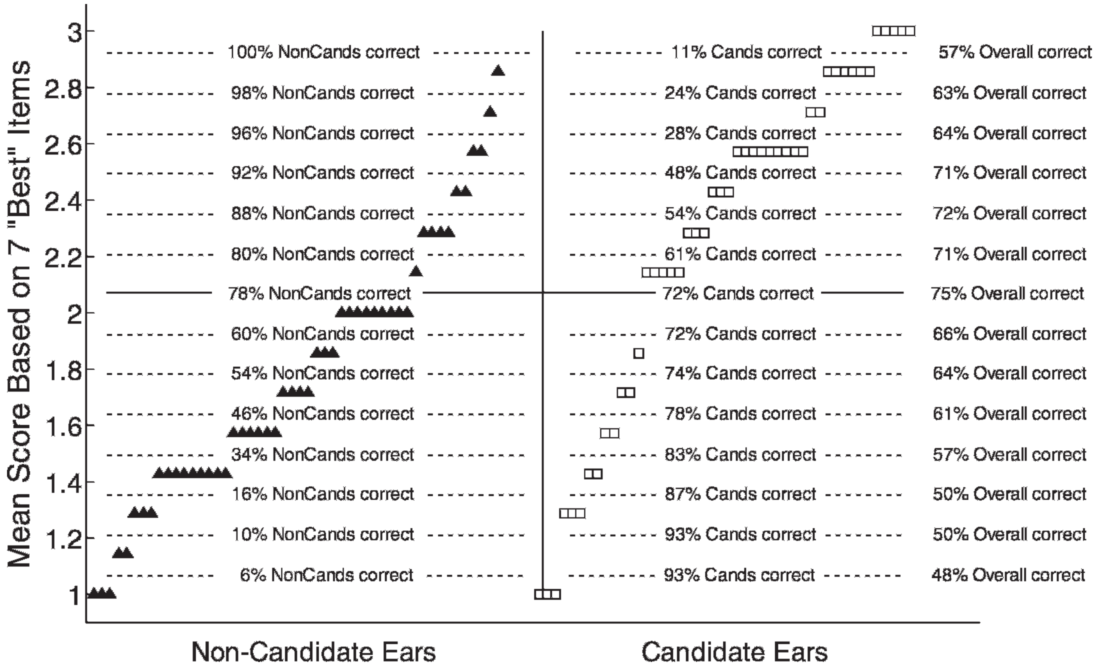

Figure 9. Mean preference rating for the seven most predictive sound samples for each of the 96 ears. Data are shown separately for the noncandidate and candidate ears.

the most potential for predicting hearing aid candidacy. The potential of these best seven items to predict hearing aid candidacy was explored in an analysis summarized in Figure 9. Shown is the mean rating of these seven items for each of the 96 ears evaluated. Mean ratings for the 50 noncandidate ears are shown on the left, and those for the 46 candidate ears are on the right. A mean rating of "3," for example, would indicate that a participant consistently preferred moderate gain when listening to each of these seven sound samples in that ear, whereas a mean rating of "1" would indicate that no gain was always preferred for each of these samples. Also given within the figure is the percentage of correct predictions for each candidate category, as well as the overall percentage of correct predictions for various mean ratings. As expected, the number of noncandidate ears generally decreases and the number of candidate ears generally increases as the mean rating (more gain) for the seven sound samples increases along the ordinate. Hence, as one moves higher along the ordinate, the percentage of correct noncandidate predictions increases, but the percentage of correct candidate predictions decreases. The best overall prediction (75% correct) was obtained at an ordinate value of 2.1, indicated by the solid horizontal line. This line and the one separating noncandidate ears and the candidate ears divide the data into four quadrants. Data points (ears) occurring in the lower left and upper right quadrants represent correct predictions of noncandidate and candidate ears, respectively. Using a mean score on these seven items of 2.1 or higher to predict hearing aid candidacy, 72 percent of hearing aid candidate ears and 78 percent of noncandidate ears are correctly identified. The highest overall prediction of hearing aid candidacy was provided by these most discriminating seven sound samples as compared to any one sound sample, to any other subset of sound samples, or to all 21 sound samples. The best overall prediction for all 21 items was 69 percent (74% correct prediction of noncandidate ears and 63% of candidate ears).

Although moderately high correct predictions of hearing aid candidacy/noncandidacy are possible with a substantially reduced number of sound samples, the predictive validity of the ELA or any subset of its 21 items is not sufficient to determine hearing aid candidacy for individual patients. The data suggest that approximately 25 percent of all patients evaluated for first-time hearing aid use would be incorrectly categorized with regard to hearing aid candidacy by the ELA. More important, the content validity of the ELA as a counseling tool would suffer should a large number of the samples be deleted. Recall that the original 14 composite sound samples were constructed to represent the everyday listening environments that are most frequently reported as problematic by patients seeking a hearing evaluation. By including a broad range of everyday listening situations, most patients can identify several sound samples on the ELA similar to those in which they experience problems and for which they seek help. On the other hand, the average 15–20 min required to administer the ELA may not be practical in some clinical settings despite its being self-administered and not requiring any audiologist intervention. A shorter version of the ELA could easily be developed in which, for example, several of the least discriminating samples are deleted (see Figure 8). However, again from a counseling perspective, this would weaken the content validity of the ELA. Further, in terms of creating realistic expectations regarding the potential benefits of amplification, it is often equally important to discuss with a patient those listening situations in which he or she does not prefer amplification (e.g., loud sounds, unfavorable SNRs) as well as those listening situations in which hearing aids might be expected to be beneficial.

It should be noted that the ability of preference ratings obtained from the ELA to predict the attending audiologists' recommendations for hearing aid use was inherently limited by the nature of the task. The ELA assesses gain preferences for sound samples that occur frequently in everyday listening. From this perspective, such preferences should be generally informative of the potential benefits of amplification. However, as previously noted, a recommendation for hearing aids in clinical practice is not determined exclusively by audiometric/acoustic factors. For example, some patients refuse hearing aids for cosmetic or financial reasons, regardless of the potential benefits to hearing that might accrue. If patients are emphatic in their refusal to use hearing aids, a recommendation for reevaluation of their hearing and additional counseling might be made, rather than a recommendation for hearing aids. Such a patient in the validation study would have been classified as a noncandidate by the attending audiologist, despite the potential to benefit from amplification based on the ELA evaluation. Similarly, some patients may prefer a unilateral fit although they could potentially benefit from bilateral amplification. Obviously, when only one hearing aid was prescribed for a patient who might otherwise be a candidate for bilateral amplification, ELA preference ratings could not predict hearing aid candidacy with perfect accuracy.

Clinical Application

The results of the validation study suggest that ELA ratings are generally predictive of clinical decisions regarding hearing aid candidacy. Based on these findings, use of these ratings as a counseling tool with patients who are being evaluated for first-time hearing aid use seems appropriate. Although the ELA was designed to be administered prior to the hearing evaluation of every patient not wearing hearing aids, clinical experience has led to more selective use. Following the diagnostic hearing evaluation, there are many patients who are clearly not hearing aid candidates. Conversely, some patients do not question their need for amplification. For these patients, obtaining ELA ratings may be of little value. In other cases, whereas the audiologist may have no doubts regarding the patient's candidacy for amplification, there may be substantial patient resistance to hearing aid use. Similarly, there are patients who present with hearing loss and/or SNR deficits of a mild degree, and both the patient and the audiologist may be uncertain regarding the potential benefit from hearing aid treatment. In these cases, ELA ratings can be quite useful.

In clinical practice, the ELA is typically administered following the hearing evaluation in cases where there is some ambivalence regarding hearing aid candidacy and/or where the hearing problems are milder in their presentation. Patients are provided the opportunity to use the ELA kiosk as part of the counseling portion of the clinic appointment. The patient is left to complete the ELA without assistance. When the patient has completed the listening task, the patient is instructed on the final screen to return to the waiting area to meet with the audiologist. In the counseling that follows, the attending audiologist can compare the results of the ELA to those listening situations described as problematic by the patient during the history and intake. Typically, one or more of the ELA sound samples represent, at least in general terms, the characteristics of the everyday listening situations that the patient noted as being difficult. Listening situation matches between those of particular difficulty to the patient in everyday listening and those where amplification was preferred (or not preferred) on the ELA are described and discussed.

It is important to note that the ELA incorporates only two conditions of single-channel WDRC amplification, which are not fit to the patient's individual hearing impairment. Further, because the current version of the ELA does not incorporate advanced signal-processing strategies (e.g., directionality, noise suppression, multichannel compression), the full potential of amplification for most patients cannot be revealed by this clinical tool. As part of the counseling, the patient is typically informed that the amplification characteristics provided on the ELA are not custom fit to his or her hearing loss and that even greater benefit may result from actual hearing aid use.

The clinical use of the ELA has proved helpful with some patients, especially those who are not convinced that their hearing loss has a significant impact on their everyday listening and/or who are pessimistic that hearing aids will be helpful. The experience of listening to the sound samples common to their everyday life unamplified and with amplification helps patients to appreciate more fully how their hearing loss impacts their daily living and how hearing aids might improve their ability to function in everyday listening situations. Although clinical experience with the ELA is encouraging, additional clinical studies are required to establish empirically the efficacy of this clinical tool.

In summary, the ELA was designed to provide naturalistic, intuitive information for the patient regarding the need for and potential benefits of hearing aid use. The gain preferences yielded by the ELA provide moderately accurate predictions of hearing aid candidacy but are not sufficient to replace traditional methods of determining candidacy in individual patients. As a counseling tool, ELA ratings can provide a useful basis for establishing the potential value of hearing aids to everyday listening for selected patients.

Acknowledgments. We wish to acknowledge Mary Cord and Lina Kubli for their assistance with data acquisition and analysis. Mead Killion produced the Knowles Electronics Manikin for Acoustic Research recordings used in this study, and Gail Gudmundsen assisted with the design of the study. Institutional Review Board approval and local monitoring of the study were provided by the Department of Clinical Investigation, Walter Reed Army Medical Center, Washington, D.C., under Work Unit #05-25020. The views expressed in this article are ours and do not reflect the official policy of the Department of the Army, the Department of Defense, or the U.S. government.

REFERENCES

Burkhard MD, Sachs RM. (1975) Anthropometric manikin for acoustic research. *J Acoust Soc Am* 58:214–222.

Chisolm TH, Johnson CE, Danhauer JL, et al. (2007) A systematic review of health-related quality of life and hearing aids: final report of the American Academy of Audiology Task Force on the Health-Related Quality of Life Benefits of Amplification in Adults. *J Am Acad Audiol* 18:151–183.

Cox RM, Alexander GC. (2000) Expectations about hearing aids and their relationship to fitting outcome. *J Am Acad Audiol* 11: 368–382.

Cox RM, Alexander GC, Gray GA. (2005) Who wants a hearing aid? Personality profiles of hearing aid seekers. *Ear Hear* 26:12–26.

Cox RM, Gilmore C. (1990) Development of the Profile of Hearing Aid Performance (PHAP). *J Speech Hear Res* 33:343–357.

Elhilali M, Chi T, Shamma SA. (2003) A Spectro-temporal Modulation Index (STMI) assessment of speech intelligibility. *Speech Commun* 41:331–348.

Gatehouse S. (1999) Glasgow hearing aid benefit profile: derivation and validation of a client-centered outcome measure for hearing aid services. *J Am Acad Audiol* 10:80–103.

Jerram JCK, Purdy SC. (2001) Technology, expectations, and adjustment to hearing loss: predictors of hearing aid outcome. *J Am Acad Audiol* 12:64–79.

Kochkin S. (2005) MarkeTrak VII: hearing loss population tops 31 million people. *Hear Rev* 13(7):16, 18–19, 22–29.

Kochkin S. (2007) MarkeTrak VII: obstacles to adult non-user adoption of hearing aids. *Hear J* 60(4):24, 26, 28, 31–34, 36–41, 44, 46, 48, 50–51.

Kricos PB, Lesner SA, Sandridge SA. (1991) Expectations of older adults regarding the use of hearing aids. *J Am Acad Audiol* 2: 129–133.

Kuk FK. (1992) Evaluation of the efficacy of a multimemory hearing aid. *J Am Acad Audiol* 3:338–348.

Larson VD, Williams DW, Henderson WG, et al. (2000) Efficacy of 3 commonly used hearing aid circuits: a crossover trial. *JAMA* 284:1806–1813.

Meister H, Walger M, Brehmer D, et al. (2008) The relationship between pre-fitting expectations and willingness to use hearing aids. *Int J Audiol* 47:153–159.

Pearsons K, Bennett RS, Fidell S. (1976) Speech levels in various environments. Prepared for the Office of Resources and Development, Environmental Protection Agency. Report No. 328. Washington, DC: Bolt Beranek and Newman, Inc.

Plomp R. (1977) Acoustical aspects of cocktail parties. *Acustica* 38:186–191.

Teder H. (1990) Noise and speech levels in noisy environments. *Hear Instrum* 41(4):32–33.

Walden BE, Demorest M, Hepler E. (1984) Self-report approach to assessing benefit derived from amplification. *J Speech Hear Res* 27:49–56.