Field Evaluation of an Asymmetric Directional Microphone Fitting

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Abstract

Laboratory evidence suggests that an asymmetric microphone fitting (omnidirectional processing in one ear and directional processing in the other) can provide a directional advantage in background noise that is as great, or nearly as great, as that provided by binaural directional processing (Bentler et al, 2004). The present study investigated whether the potential benefit of an asymmetric fitting observed in the laboratory extends to real-life listening. Specifically, ease of listening was compared across a variety of real-life listening situations for asymmetric microphone fittings and bilateral omnidirectional processing. These ratings were compared to determine whether the asymmetric fitting provided an advantage in listening situations in which directional microphone processing is generally preferred and/or a disadvantage in listening situations in which omnidirectional microphone processing is generally preferred. Results suggest that an asymmetric fitting may be a viable option for patients who cannot or do not switch microphone modes.

Key Words: Directional microphones, ease of listening, hearing aids, speech recognition

Abbreviations: AASC = Army Audiology and Speech Center; ASYM = asymmetric; HAUL = Hearing Aid Use Log; IEEE = Institute of Electrical and Electronic Engineers; OMNI = omnidirectional; RAU = rationalized arcsine unit; SNR = signal-to-noise ratio

Sumario

La evidencia de laboratorio sugiere que una adaptación asimétrica de micrófono (procesamiento omnidireccional en un oído y procesamiento direccional en el otro) puede aportar una ventaja direccional en medio de ruido de fondo que es tan buena, o al menos casi tan buena, como la otorgada por un procesamiento direccional biauricular (Bentler y col., 2004). El presente estudio investigó si el beneficio potencial de una adaptación asimétrica observada en el laboratorio se extiende a la audición en la vida real. Específicamente, la facilidad de escucha fue comparada en una variedad de situaciones auditivas en la vida real utilizando adaptaciones asimétricas de micrófono y de procesamiento omnidireccional bilateral. Estos resultados fueron comparados para determinar si la adaptación asimétrica aportaba una ventaja a la hora de escuchar, situaciones donde se suele preferir el procesamiento por micrófono direccional, y/o, una desventaja en situaciones auditivas donde se prefiere el procesamiento con micrófono omnidireccional. Los resultados sugieren que

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una adaptación asimétrica puede ser una opción viable para pacientes que no pueden o no quieren cambiar la modalidad de micrófono.

Palabras Clave: Micrófonos direccionales, facilidad de escucha, auxiliares auditivos, reconocimiento del lenguaje

Abreviaturas: AASC = Centro de Audición y Lenguaje de la Armada; ASYM = asimétrico; HAUL = Bitácora de Uso del Auxiliar Auditivo; IEEE = Instituto de Ingenieros Eléctricos y Electrónicos; OMNI = omnidireccional; RAU = unidad de arcoseno racionalizada; SNR = tasa señal/ruido

Hearing aids equipped with directional microphones provide amplification for sounds coming from in front of the wearer and attenuate sounds coming from other directions. In noisy listening situations in which the listener is facing the signal and the signal and noise are spatially separated, directional microphone technology offers the potential for improved speech understanding. Studies in several laboratories have demonstrated the benefit provided by directional microphones for hearing-impaired listeners in noise (e.g., Valente et al, 1995; Ricketts and Dahr, 1999; Walden et al, 2000). Because there are many listening situations in which directional processing would not be desirable (e.g., the signal of interest is behind or beside the listener), most hearing aids equipped with directional microphones are switchable between the omnidirectional mode and the directional mode. Generally, the omnidirectional mode is the default setting and the directional mode is accessed via a switch on the hearing aid or with a remote control.

A survey of patients who had purchased manually switchable omnidirectional/directional hearing aids revealed that nearly one-third of the patients were not using the directional microphone feature (Cord et al, 2002). Rather, they left their hearing aids set in the default omnidirectional mode all the time. When questioned as to why they were not switching between modes, many stated that they did not have a clear understanding of when they should use the directional setting. Some patients indicated that they did not notice a significant improvement in their ability to understand speech when they had tried the directional mode. Others stated that it was just too much trouble to use the switch or they had trouble finding the switch when they tried to use it. In any case, it seems clear that patients who fail to switch to the directional mode when environmental conditions favor directional processing deny themselves the benefit of this technology.

Some manufacturers have introduced hearing aids that automatically switch between the omnidirectional and directional modes based on some analysis of the acoustic environment. This would appear to be a good option for patients who do not switch microphone modes manually. However, clinical experience with these automatic directionality devices suggests limited patient acceptance. It appears that the current automatic switching algorithms incorporated into these signal processors are not selecting the preferred microphone mode in many listening environments (Fabry et al, 2006). This is probably due not only to the limitations in current signal processing algorithms but also to the fact that many listening situations are dynamic rather than static, with people moving around in the environment. Equally important is the fact that signal processors cannot read the listener's mind. If, for example, a listener is in face-to-face communication but wants to divert his attention to a signal elsewhere in the environment, an automatic switching algorithm based on the acoustics of the processed signals cannot react to the hearing aid wearer's intent to change the polar pattern.

This study explored whether patients who have bilateral hearing aids with manually switchable omnidirectional/directional modes and who do not switch their aids to the directional mode can benefit from an asymmetric microphone fitting, in which one ear is fit with an omnidirectional microphone and the other ear with a directional microphone. This type of fitting would allow both omnidirectional and directional processing to be simultaneously available to the listener. Evidence from two recent laboratory studies (Bentler et al, 2004; Hornsby and Ricketts, 2005) suggests that an asymmetric hearing aid fitting may provide most, if not all, of the directional benefit provided by a bilateral directional fitting.

Bentler et al (2004) compared five hearing aid microphone configurations: binaural omnidirectional processing, three different types of binaural directional processing (cardioid, supercardioid, and hypercardioid polar responses), and an asymmetric ("monofit") condition, in which the left hearing aid was set to omnidirectional and the right hearing aid to directional processing. Speech stimuli were presented directly in front of the listener in a diffuse noise. The asymmetric condition yielded performance results that were comparable to the binaural directional microphone conditions and significantly better than the binaural omnidirectional fitting.

Hornsby and Ricketts (2005) assessed speech recognition ability in three conditions: (1) speech in front, noise diffuse; (2) speech in front, noise from the left; and (3) speech from the right, noise from the left. Under each speech-in-noise test condition, four bilateral hearing aid fitting configurations were evaluated: binaural omnidirectional, binaural directional, asymmetric with directional processing on the right ear, and asymmetric with directional processing on the left ear. As in the study by Benter et al (2004), performance with an asymmetric configuration was significantly better than for the binaural omnidirectional configuration for the two conditions in which the signal was located in front of the listener. In contrast to the findings of Bentler et al (2004), however, speech recognition was significantly better for the binaural directional than for either asymmetric fitting in the diffuse noise condition. For the third condition, with speech presented from the right and noise from the left, the binaural omnidirectional fitting resulted in significantly better speech understanding in noise than the binaural directional fitting or the asymmetric fitting with directional processing on the right ear (side toward speech). Taken together, the results of these studies suggest that an asymmetric fitting may provide an advantage over a binaural omnidirectional fitting for speech understanding in noise, at least in some listening situations. The obvious advantages of an asymmetric fitting are that no switching is required and that at least one of the two hearing aids will be in the preferred microphone mode in most real-life listening situations.

It is unknown whether the benefit observed in a laboratory environment (Bentler et al, 2004; Hornsby and Ricketts, 2005) extends to real-life listening situations, which may be very different from controlled test conditions (Walden et al, 2000). Directional microphones become less effective as the distance between the signal and the listener increases and as reverberation increases (Hawkins and Yacullo, 1984; Ricketts and Dittberner, 2002) and as the spatial separation of the signal and noise diminishes (Leeuw and Dreschler, 1991). It is also unknown what impact an asymmetric microphone fitting strategy might have on the listener's ability to localize sound. Hence, this investigation sought to determine empirically whether the directional benefit for asymmetric hearing aid fitting demonstrated in the laboratory translates to real-life listening environments.

METHODS

Participants

Twelve individuals participated in the study. All but one were male, reflecting the demographics of the Army Audiology and Speech Center's (AASC) patient population. Participants ranged in age from 56 to 82 years, with a mean of 73 years. All participants were experienced users of amplification, with 1.5 to 20 years experience (average = 11 years). At the time of enrollment, all participants had been fitted binaurally with manually switchable omnidirectional/directional hearing aids at the AASC at least three months and not more than three years prior to enrollment in the study. Reported hours of daily hearing aid use for the 12 participants ranged from 8 to 16, averaging 13 hours per day. Despite using their hearing aids regularly, they were regarded as failures as users of directional processing. Ten of the participants indicated that they never used the directional mode, and two participants (S7 and S9) indicated that they rarely used it. Seven of the participants (S1, S2, S5, S7, S8, S10, and S12) stated that the directional mode did not seem to provide any benefit over the default omnidirectional mode in the situations they had tried. Four participants (S3, S4, S6, and S9) stated that they just leave the hearing aid in the default program. One participant (S11) did not know what the different programs of his hearing aid were for. To preclude the enrollment of participants who were unlikely to encounter situations in their everyday lives in which directional microphones could provide benefit, potential participants were asked to identify five listening situations in which they continued to have difficulty communicating with their hearing aids. At least three of the five listening situations identified had to be those in which directional microphone processing has the potential to improve performance; that is, situations in which noise was present and the signal was in front of and relatively near to the listener (Walden et al, 2004).

All participants had bilateral, symmetric sensorineural hearing impairment. Sensorineural hearing loss (cochlear site of lesion) was verified by differences between air- and bone-conduction thresholds of 10 dB or less, and by type A tympanograms (Jerger, 1970). Monosyllabic word recognition (NU-6) in quiet was 50% or better in each ear at a comfortable listening level. The mean audiogram of the 12 participants is shown in Figure 1.

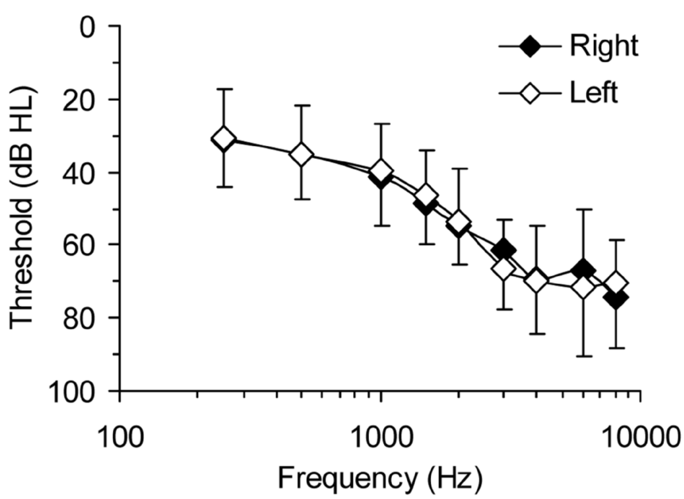

Figure 1. Mean pure-tone thresholds for the 12 participants. Error bars in this and all subsequent figures indicate one standard deviation.

Hearing Aids

Participants' own digital programmable manually switchable directional microphone hearing aids were used for this study. These represented a number of different manufacturers and models. Table 1 lists the hearing aid style and directional microphone type for each participant's hearing aids. Seven participants had hearing aids with fixed directionality, and five had hearing aids with adaptive directionality. The term "adaptive directionality" will be used in this paper to describe signal processing in which the directional polar pattern may vary adaptively (i.e., place one or more nulls in the direction of noise source[s]) but never goes to an omnidirectional pattern.

A listening check and standard test-box measures were performed to verify that the hearing aids were in good working order. Additionally, potential participants were screened with a speech recognition in noise test (described below) to confirm that they obtained a directional advantage of at least 15% in a laboratory setting. This screening was done to assure that the directional microphones were working and that participants had the potential to benefit from directional processing in real-life listening.

Speech Recognition in Noise Testing

Test materials consisted of the Institute of Electrical and Electronic Engineers (IEEE)/Harvard sentences (IEEE, 1969), produced by a female talker of American English. The digitized IEEE materials consist of phonetically balanced sentences, each containing five key words that form the basis for scoring. The sentences contain few contextual cues to help identify the key words (e.g., "The birch canoe slid on the smooth planks"). The sentences are organized into 72 lists, each containing ten sentences.

Testing was conducted in sound field in a 3.0 m by 2.5 m sound-treated audiometric test suite. Test sentences were presented at

Table 1. Hearing Aid Style, Directional Microphone Type, and Directional Advantage (DA) for 12 Participants

Participant	Hearing Aid Style	Directional Microphone Type	DA (%)
S1	BTE	Adaptive	27
S2	Half-shell ITE	Fixed Hypercardioid	17
S3	Full-shell ITE	Adaptive	22
S4	Half-shell ITE	Fixed Hypercardioid	15
S5	BTE	Fixed Hypercardioid	18
S6	Full-shell ITE	Adaptive	33
S7	BTE	Adaptive	18
S8	Full-shell ITE	Adaptive	54
S9	Half-shell ITE	Fixed Hypercardioid	32
S10	BTE	Fixed Supercardioid	37
S11	Half-shell ITE	Fixed Hypercardioid	28
S12	Half-shell ITE	Fixed Hypercardioid	21

Note: BTE = behind the ear; ITE = in the ear.

an average conversational level of 65 dB SPL through a wall-mounted loudspeaker (B&W model LM-1) positioned at 0 degrees azimuth. Uncorrelated competing speech-shaped noise came from three wall-mounted loudspeakers (Rock Solid) positioned at 90, 180, and 270 degrees azimuths. The noise level required to create the specific signal-to-noise ratio (SNR) was based on the overall level of the combined three noise sources at the position of the listener's head. All loudspeakers were positioned at ear level, and the listener was seated in the center of the test room. The front and rear loudspeakers were each 120 cm, and each side speaker 95 cm, from the center of the participant's head. Presentation of the test sentences was under computer control. Participants responded aloud to each test sentence, and the test administrator scored the number of correct key words for each sentence.

Screening

A speech recognition in noise screening with hearing aids set to binaural omnidirectional processing and binaural directional processing was conducted to verify that a directional advantage was obtained by each participant. The directional advantage was calculated as the directional score minus the omnidirectional score. Two lists of the IEEE sentences were used for each condition. Testing was conducted at 0 dB SNR. If a directional advantage of at least 15% was not obtained at this level, the SNR was adjusted in 3 dB steps until the 15% criterion was achieved. Seven of the participants achieved a 15% directional advantage at 0 dB SNR; four participants (S2, S4, S7, and S12) required a more difficult SNR of -3 dB; and one participant (S10) required an SNR of -6 dB to obtain a 15% directional advantage. Individual directional advantage scores for the 12 participants are listed in Table 1. In a previous study using the same test materials and procedures, 0 dB SNR corresponded to the midpoint of the performance-intensity function and was the condition in which 30 of the 31 participants obtained a directional advantage of at least 15% (Walden et al, 2005). The participants in the current study had mean key word scores of 30.3% (range: 12–47%) and 57.2% (range: 27–86%) for the binaural omnidirectional and binaural directional conditions respectively.

Testing

Tests of speech recognition in noise were administered for (1) bilateral omnidirectional processing, (2) bilateral directional processing, (3) asymmetric with directional to right ear and omnidirectional to left ear, and (4) asymmetric with directional to left ear and omnidirectional to right ear. Three lists of the IEEE sentences were used for each condition so that each of the four scores was based on a total of 150 key words. Testing was randomized across lists and conditions. The SNR used for this testing was the SNR that was established for each participant during the screening (0, -3, or -6 dB).

Hearing Aid Use Log (HAUL)

The Hearing Aid Use Log (HAUL) is a daily journal used to record microphone preferences, subjective measures of performance with hearing aids, and descriptions of real-life listening environments during hearing aid field trials. Variations of the HAUL have been used in two previous studies (Surr et al, 2002; Walden et al, 2004). In the current study, a check-box format was used to characterize the listening situation that the participant encountered in terms of location of the signal of interest (front or other), distance of signal (<10 feet or >10 feet), and absence or presence of background noise. With these three characteristics, situations in which directional processing is generally preferred can be identified (i.e., signal in front, signal source relatively near, and background noise present [Walden et al, 2004]). All other situations are considered to be ones in which omnidirectional is typically preferred or where there would be no distinct preference between omnidirectional and directional processing and, presumably, where the hearing aid would be left in the default omnidirectional mode. In addition, a visual-analog rating scale was used to assess the perceived difficulty of each listening situation. Participants indicated their response to the question "Was this an easy or difficult listening situation for you?" by placing an "X" on a horizontal line with 11 equally spaced tick marks and the verbal descriptors "very difficult" and "very easy" at the endpoints. A template was later applied to place a numerical value from 0–10 corresponding to the location of the "X" on the horizontal line, with higher numbers indicating greater reported ease.

The HAUL forms were used to record the characteristics of every listening situation encountered during a total of seven days. Because it was important that the listening situations recorded be as representative as possible of listening situations normally encountered by the participants in daily living, participants were requested to complete journals in one-half day or one-third day blocks of time, depending on whether the participant preferred two-week or three-week trials. For the half-day blocks, participants filled out the HAULs from morning to midafternoon (rising to 3 PM) for one week, and afternoon to evening (3 PM to retiring) for a second week. For the one-third day blocks, the divisions were mornings (rising to noon) for one week, afternoons (noon to 5 PM) a second week, and evenings (5 PM to retiring) a third week. The order in which these one-half or one-third day blocks of data were acquired was balanced across participants over the two or three weeks of the trials. Separate two- or three-week trials were conducted sequentially for the bilateral omnidirectional and the asymmetric fitting conditions.

Participants were instructed that during the seven days surveyed in each trial, they should use the HAUL to describe every listening situation they encountered that was of sufficient duration. Only listening situations in which "active" listening took place were to be included. This meant situations in which the participant was actively listening to speech or nonspeech sounds (e.g., music, sounds of nature) were to be included, and passive listening situations, such as reading the newspaper or working at a computer, were excluded. Listening situations that were encountered repeatedly (e.g., conversing with a spouse at the dinner table, listening to the radio in the car) were to be rated independently each time the participant encountered the listening situation.

Procedures

Because the participants in this clinical study chose never or rarely to use the program switch on their hearing aids, the investigation was designed so that no switching of microphone modes would be required of them. The binaural omnidirectional control condition (OMNI) and the experimental asymmetric condition (ASYM) were evaluated in sequential field trials, with the order of the trial conditions counterbalanced across participants. For each fitting, the configuration to be evaluated was programmed into memory 1 of each hearing aid, and the memory switch was deactivated to avoid accidental changes to other program settings during the trial periods. The participants were not told the nature of the two hearing aid fitting conditions or how they differed but were simply told that they processed sound differently.

Participation required three clinic visits over a four- to six-week period. At the first visit, potential participants' hearing and hearing aids were evaluated using standard clinical tests to assure that all inclusion criteria were met. This included an aided speech recognition in noise screening to verify that a directional advantage was obtained in the laboratory, using the procedures described previously. If all the requirements were met, the participant's hearing aids were programmed to the assigned configuration (OMNI or ASYM). For the asymmetric condition, half of the participants had the directional mode fit to the right ear, and the remainder of the participants had the directional mode fit to the left ear.

In most cases, participants' hearing aids had been programmed with compensation for low-frequency roll-off in the directional mode at the time of their hearing aid fitting. For the participants whose omnidirectional and directional programs had not been equalized, this was accomplished before the ASYM configuration was programmed into the hearing aids. This was done to minimize the perception of loudness differences between the two ears that can result from low-frequency roll-off typically associated with directional microphones. Also, if there were differences in the amount of noise reduction between the two modes, both were programmed to the noise reduction setting for the patient's own omnidirectional program.

Participants were given practice in filling out HAUL forms at several different locations in the clinic. Once practice had been completed, the participant was provided with a booklet of HAUL forms to be filled out daily. At the end of Visit 1, the participant began the first of two sequential two- or three-week field trials. During each trial, the participants' progress in filling out the HAUL forms was monitored weekly via telephone interviews with one of the investigators to determine whether she or he was completing the logs within the time allotted during each trial period.

After completion of the first trial, the participant returned for the second visit to the clinic, at which time the completed HAUL forms were reviewed by one of the investigators. The hearing aids were programmed to the second configuration, and new booklet of HAUL forms was provided for the second trial period.

On the final visit, the HAUL forms for the second trial period were collected and reviewed. In addition, the participants' subjective overall preferences between the hearing aid fittings in the first and second trials were obtained.

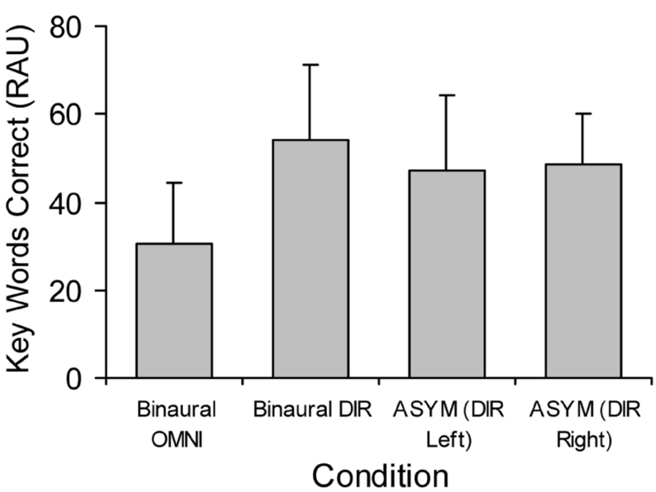

Figure 2. Mean IEEE scores (RAU) obtained in binaural omnidirectional, binaural directional, and the two asymmetric fittings (omnidirectional-right/directional-left and directional-right/omnidirectional-left) for the 12 participants.

RESULTS

Speech Recognition in Noise Testing

Figure 2 displays the mean IEEE scores obtained in binaural omnidirectional, binaural directional, and the two asymmetric fittings (omnidirectional-right/directional-left and directional-right/omnidirectional-left) for the 12 participants during the final clinic visit. Recall that the test conditions involved the test sentences presented from the front and noise presented from the sides and back. Hence, directional processing should be favored. The IEEE scores were transformed into rationalized arcsine units (RAU) to avoid floor and ceiling effects (Studebaker, 1985). A repeated-measures ANOVA comparing IEEE scores for the four hearing aid fitting conditions indicated a significant main effect ($F_{3, 33} = 24.09$, $p < 0.001$). Post-hoc pairwise comparisons, using the Tukey test, revealed that the binaural directional and the two asymmetric

Table 2. Distribution of HAUL Scores across Type of Listening Situation and within Each Microphone Condition

	Microphone Condition OMNI	ASYM	Total
Favor Directional Processing	233 (14%)	191 (12%)	424 (26%)
Favor Omnidirectional Processing/No Preference	554 (35%)	634 (39%)	1188 (74%)
Total	787 (49%)	825 (51%)	1612 (100%)

conditions did not differ significantly from each other. Performance with the binaural omnidirectional fitting was significantly worse than all other conditions (p < 0.001).

Hearing Aid Use Log (HAUL)

HAUL data were obtained during a total of seven days for OMNI and seven days for ASYM fitting configurations. A total of 1612 HAULs were collected from the 12 participants. The distribution of HAULs across and within each type of listening situation and microphone condition are displayed in Table 2.

For each participant, average ease of listening was calculated for HAUL forms completed during the OMNI trial and for those completed during the ASYM trial. Recall that ease of listening refers to the final item on the HAUL on which participants indicated the perceived ease or difficulty of the listening situation, with higher numbers indicating greater ease. The mean of the average ease ratings for the 12 participants for the two conditions (Figure 3) revealed a small difference, with the ASYM condition, on average, providing easier listening than the OMNI condition. A paired t-test indicated that this difference was statistically significant (t = -2.61, p = 0.02). Examination of the individual data revealed that this was not true for every participant. In Figure 4, the individual difference scores (OMNI score subtracted from the ASYM score) are displayed for each participant. Bars above the horizontal line indicate greater reported ease with the ASYM fitting. The small mean difference between the conditions appears to be mainly attributable to 5 of the 12 participants. However, none of the 12 participants reported substantially greater ease with the OMNI as compared to the ASYM condition.

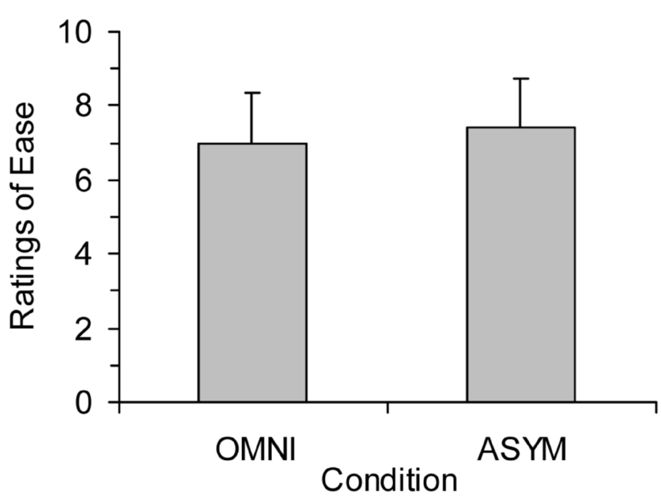

Figure 3. Mean ratings of ease of listening for the two microphone conditions.

The field data were further analyzed by sorting the HAULs into two categories based on the findings of Walden et al (2004). The first category included listening environments in which directional processing is typically preferred. These included all situations in which the signal is relatively close to and in front of the listener, and background noise is present. These situations represented 424 HAULs, or 26% of all the HAULs. The second category included all listening environments in which omnidirectional processing is typically preferred or in which neither microphone mode is typically preferred. This second category included listening situations in which noise was absent, or in which noise was present with the signal far from and/or not in front of the listener. These situations represented the remaining 1188 (74%) of the HAULs. Mean ratings of listening ease for each category, displayed in Figure 5, were compared to determine whether (a) performance in listening situations in which directional processing is typically preferred

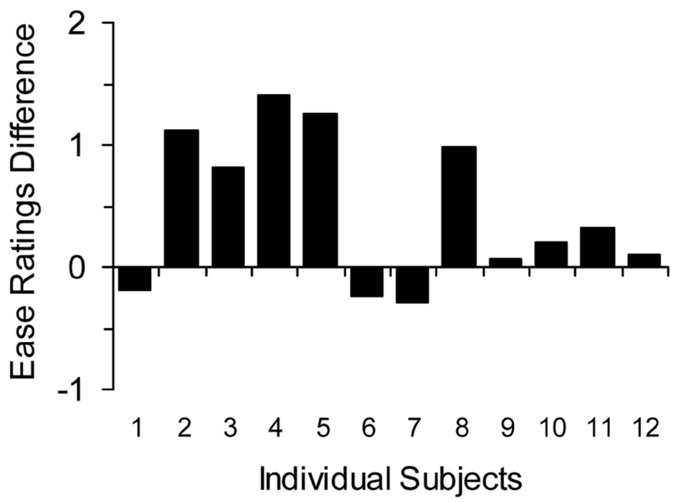

Figure 4. Individual difference ratings for ease of listening. The difference score was calculated by subtracting the OMNI score from the ASYM score for each participant. Thus, bars above the line indicate greater ease for the ASYM condition.

is improved by the asymmetrical fitting and (b) performance in listening situations in which omnidirectional processing is typically preferred is diminished by the asymmetrical fitting. A two-way repeated measures ANOVA was conducted to address these questions. The effect of fitting condition (OMNI vs. ASYM) on performance was significant

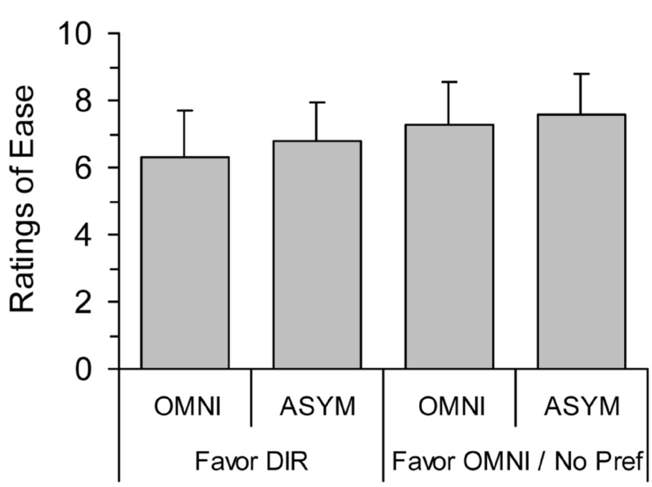

Figure 5. Mean ratings of listening ease for the two microphone conditions in listening situations where directional processing is typically preferred and in listening situations where omnidirectional processing is generally preferred or where there is no preference.

($F_{1, 11}$ = 8.33, p = 0.02), as was the effect for category (directional vs. omnidirectional/no preference) of listening situation ($F_{1, 11}$ = 15.79, p = 0.002). There was no statistically significant interaction between these effects.

Fitting Preference

At the conclusion of the two trial periods, participants were asked if they had a preference for one fitting over the other. Three participants (S1, S6, S8) preferred OMNI; four participants (S3, S4, S5, S10) preferred ASYM; and five had no preference. Preferences were not related to the order of trials.

Directional Microphone Type

As noted above, some participants had hearing aids with fixed directionality and others had hearing aids with adaptive directionality, in which the directional polar pattern may vary adaptively (but never goes to an omnidirectional pattern). Statistical analyses were conducted to determine if the type of directional processing influenced the laboratory testing or field results. A repeated measures ANOVA revealed that the effect of directional microphone type (fixed vs. adaptive) on the laboratory tests of speech recognition in noise performance was not significant ($F_{1, 10}$ = 0.77, p = 0.40). Nor was there an effect of directional microphone type on field ratings of overall ease (t = 1.25, p = 0.32) or the rating of ease for situations that favor directional processing (t = 0.28, p = -0.79).

DISCUSSION

The purpose of this clinical investigation was to determine whether an asymmetric fitting would provide an advantage over a binaural omnidirectional fitting in real-life listening situations for a group of patients who do not switch modes on their manually switchable hearing aids. More specifically, we wanted to know if an asymmetric fitting would be advantageous in situations where directional processing is known to be preferred (Walden et al, 2004). We also wanted to know whether an asymmetric fitting would have detrimental effects in listening situations where omnidirectional processing is typically preferred.

The results of the field trials revealed that, on average, participants reported greater ease of listening with the asymmetric fitting than the binaural omnidirectional fitting. However, when the HAULs were analyzed separately for the two types of listening situations (favor omnidirectional processing, favor directional processing), this difference remained only for listening situations in which directional processing is generally expected to be favored. Participants reported significantly greater ease with the ASYM fitting as compared to the OMNI fitting in these conditions ($t = -2.30$, $p = 0.04$). Figure 6 displays individual subjects' difference scores for the listening situations in which directional processing is known to be preferred. The majority of participants (9 of the 12) reported greater ease with the ASYM fitting in these conditions. Hence, directional processing presented to a single ear appeared to provide a directional advantage in terms of ease of listening in real-life situations for this group of patients who rarely or never used the directional mode of their hearing aids. In situations where omnidirectional processing is typically preferred or where there is generally no preference, ratings of ease were not significantly different between the two fittings ($p = 0.08$), suggesting that the use of a directional microphone on a single ear does not create a detriment in these situations.

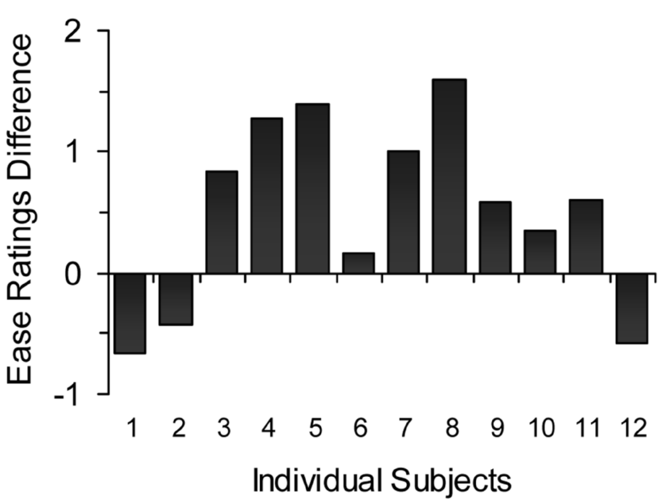

Figure 6. Individual difference ratings for ease of listening in situations where directional processing is typically preferred. The difference score was calculated by subtracting the OMNI score from the ASYM score for each participant so that bars above the line indicate greater ease for the ASYM condition.

The results of laboratory testing revealed that all three fitting configurations that included directionality (binaural directional, omnidirectional-right/directional-left and directional-right/omnidirectional-left) provided comparable directional advantage when speech was presented from in front of the listener and the speech and noise were spatially separated. These results were in good agreement with those of Bentler et al (2004), who also presented speech from the front in a diffuse noise environment. In contrast, Hornsby and Ricketts (2005) found that subjects performed significantly better with a binaural directional microphone fitting than with either asymmetric fitting under similar laboratory listening conditions. These discrepancies are likely due to methodological differences among the studies. Specifically, loudspeaker locations, presentation levels, and reverberation times varied across the studies. Despite these differences, in all three studies participants performed significantly better with the asymmetric fitting than with the binaural omnidirectional fitting in noisy situations when the signal was presented from the front.

In directional microphone studies that have included both laboratory tests and field trials, the directional benefit measured in the laboratory has been much greater than the benefit reported by participants in the field (e.g., Nielsen and Ludvigsen, 1978; Valente et al, 1995; Walden et al, 2000). This is undoubtedly due, in large measure, to the fact that the acoustic characteristics of most real-life listening situations are quite different from those of the controlled laboratory test environment. In real life, factors such as reverberation, distance, and movement of the signal or the listener are not controlled and are often dynamic, all of which tend to limit directional processing. Field trials depend on participants' reports of their performance. Additionally, in the current investigation, obtaining statistically significant effects depended on the accuracy of participants' descriptions of the listening environments. Thus, there was potential for considerable error in the field data. The fact that a statistically significant difference between the two fittings was obtained in this study is notable, particularly since the comparisons were made in sequential trials rather than as direct comparisons.

In this field trial of asymmetric fittings, the omnidirectional and directional processing was assigned in counterbalanced order to the right or left ear of each participant. It is unknown whether a given individual might perform better in real-life situations with a particular asymmetric fitting configuration. The laboratory testing of speech in noise with each asymmetric configuration revealed no sign of an ear effect. Six of the 12 participants performed somewhat better with directional processing on the right ear, and six performed better with directional processing on the left ear. Differences between the two fittings varied by .6 to 12.9 RAU across the participants. It is not known if these differences between ears are clinically significant for any particular participant. It is also unknown whether the variability between ears was due to inherent differences between ears for speech in noise processing, differences in directivity between the individuals' right and left hearing aids, differences in real-life listening situations encountered, or a combination of these factors. Further research is needed to clarify these issues and to provide guidance for determining which ear should be fitted with which type of microphone processing to optimize an asymmetric fitting.

Because of the clinical nature of the study, direct measures were not available to determine the directivity provided by the directional microphones of the participants' hearing aids. A listening check of each hearing aid suggested that they were operating properly. Additionally, all participants achieved a directional advantage of at least 15% in the laboratory. Nevertheless, the actual amount of directivity being provided by each instrument is undetermined because the directionality of the hearing aids was not verified by electroacoustic measurements. Therefore, it is possible that some of the variability for the two microphone conditions in the laboratory testing and in the field trial may be related to less than optimal directivity in the directional mode.

At least one laboratory study has suggested that bilateral symmetric fittings may provide improved speech recognition as compared to asymmetric fittings in some noisy everyday listening environments (Hornsby and Ricketts, 2005). Thus, patients who are fit with manually switchable devices should be encouraged to experiment with the different microphone modes in various listening environments. By doing so, most patients will eventually be able to determine the listening situations in which they will derive benefit from directional processing (Cord et al, 2002). However, an asymmetric fitting may be a reasonable option for patients who, even after appropriate counseling and training, cannot or will not switch programs. This strategy may also overcome some of the problems that are inherent in automatic switching.

CONCLUSIONS

Participants, on average, reported greater listening ease overall when using an asymmetric fitting as compared to an omnidirectional fitting in real-life situations. Importantly, greater ease of listening was reported for the asymmetric fitting in situations where noise was present and the signal was in front of and relatively close to the listener. These environmental variables are associated with a preference for directional microphone processing. For all other listening situations (that is, situations where omnidirectional processing tends to be preferred or where there is generally no preference between omnidirectional and directional microphone processing), there was no significant difference in reported ease of listening. In the laboratory, listeners performed significantly better on a speech-in-noise task with the asymmetric fitting as compared to a binaural omnidirectional configuration. Taken together, these results suggest that an asymmetric fitting can provide a directional advantage in some noisy listening situations and does not have a detrimental effect when directional processing is inappropriate.

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