

# Relationship between Laboratory Measures of Directional Advantage and Everyday Success with Directional Microphone Hearing Aids

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## Abstract

The improvement in speech recognition in noise obtained with directional microphones compared to omnidirectional microphones is referred to as the directional advantage. Laboratory studies have revealed substantial differences in the magnitude of the directional advantage across hearing-impaired listeners. This investigation examined whether persons who were successful users of directional microphone hearing aids in everyday living tended to obtain a larger directional advantage in the test booth than persons who were unsuccessful users. Results revealed that the mean directional advantage did not differ significantly between patients who used the directional mode regularly and those who reported little or no benefit from directional microphones in daily living and, therefore, tended to leave their hearing aids set in the default omnidirectional mode. Success with directional microphone hearing aids in everyday living, therefore, cannot be reliably predicted by the magnitude of the directional advantage obtained in the clinic.

**Key Words:** Directional advantage, directional microphones, hearing aids

**Abbreviations:** AASC=Army Audiology and Speech Center; HINT = Hearing in Noise Test; LSS = Listening Situations Survey; SNR = signal-to-noise ratio

## Sumario

La mejoría en el reconocimiento del lenguaje en presencia de ruido, obtenida con micrófonos direccionales comparada con micrófonos omnidireccionales se identifica como ventaja direccional. Los estudios de laboratorio han revelado diferencias sustanciales en la magnitud de ventaja direccional en diferentes sujetos con trastornos auditivos. Esta investigación trató de establecer si las personas consideradas usuarios exitosos de auxiliares auditivos con micrófonos direccionales en condiciones cotidianas, tendían a obtener una ventaja direccional mayor en el cuarto de evaluación que aquellas personas consideradas usuarios no exitosos. Los resultados revelaron que la ventaja direccional promedio no difería significativamente entre los pacientes que utilizaban regularmente el modo direccional y aquellos que reportaban poco o ningún beneficio de los micrófonos direccionales en situaciones cotidianas, y que, por lo tanto, tendían a dejar, por defecto, sus auxiliares auditivos en el modo omnidireccional. El éxito con los auxiliares auditivos con micrófono direccional en situación cotidianas, por tanto, no puede predecirse confiablemente por la magnitud de la ventaja direccional obtenida en la clínica.

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**Palabras Clave:** Ventaja direccional, micrófonos direccionales, auxiliares auditivos

**Abreviaturas:** AASC = Centro de Audiología y Lenguaje del Ejército; HINT = Prueba de Audición en Ruido; LSS = Estudio de situaciones auditivas; SNR = tasa de relación señal/ruido

Difficulty understanding speech in the presence of background noise is a common complaint of hearing aid users and a primary reason for dissatisfaction with hearing aids (Kochkin, 1993). Persons with impaired hearing require a more favorable signal-to-noise ratio (SNR) to understand speech in background noise than do persons with normal hearing (Dubno et al, 1984; Gelfand et al, 1988; Bronkhorst and Plomp, 1990). Currently, directional microphones are the only option available on wearable hearing aids that can improve speech understanding in noise. Assuming that the listener is facing the signal source and that the background noise is not coming from the same location (i.e., signal and background noise are spatially separated in the listening environment), directional microphone technology offers the potential for improving the SNR at the listener's ear.

The directional advantage is the improvement in speech recognition in noise obtained with directional microphones in comparison to omnidirectional microphones. It is often expressed as the decibel difference in SNRs between the omnidirectional and directional modes required to achieve some criterion performance level, typically 50 percent correct speech recognition. Numerous laboratory studies have demonstrated the advantage that directional microphones can provide when listening to speech in noise. Valente et al (1995) reported the directional microphone provided a mean advantage in SNR of 7.6 dB over the omnidirectional condition for 50 hearing-impaired listeners evaluated. However, the directional advantage varied considerably across listeners, from 3.5 dB to 16.1 dB. This variability in directional

advantage is particularly noteworthy, considering that each 1 dB SNR improvement could produce 8.5 percent improvement or more in speech recognition (Nilsson et al, 1994). In a similar study, Agnew and Block (1997) reported a mean directional advantage of 7.5 dB, with differences between participants ranging from 2.3 to 14.6 dB.

Clearly, the directional advantage obtained with hearing-impaired persons in a test booth can vary considerably, even for the same hearing aids and test conditions. In an effort to identify the source(s) of this variability, Ricketts and Mueller (2000) examined the results of three separate laboratory investigations to determine whether slope of the audiometric configuration, amount of high-frequency hearing loss, and/or the aided omnidirectional performance for a speech-in-noise intelligibility task were related to directional advantage. They found no relationship between the slope of the audiometric configuration or amount of high-frequency hearing loss and the magnitude of advantage from directional microphones for any of the three studies. However, there was a significant, negative relationship between aided omnidirectional performance and directional advantage obtained from the data of one study. They concluded that, although some individuals received significantly more advantage from directional microphones than others, the magnitude of directional advantage could not be predicted from the audiometric variables evaluated. Jespersen and Olsen (2003) further examined the relationship between omnidirectional performance in noise and directional advantage, controlling for the slope of the

hearing loss. The effect of the degree of hearing loss was also evaluated. They found that neither omnidirectional performance in noise nor degree of hearing loss could predict directional advantage.

Not only does the advantage obtained from directional microphones vary across patients in the test booth, substantial individual variability in success with directional technology is observed in everyday living as well. Cord et al (2002) explored the perceived benefits of directional microphone technology in real-world situations to patients who had been fit with switchable omnidirectional/directional hearing aids. These hearing aids incorporate both directional and omnidirectional microphone modes into a single multimemory device, allowing the wearer to switch between the two microphone configurations depending on the listening situation. Telephone interviews and paper-and-pencil questionnaires were used to assess perceived performance with each microphone type. Although the majority of patients reported that they used the directional microphone mode regularly and were generally satisfied with the performance of their hearing aids, a substantial number (23 percent) reported that they did not use the directional microphone feature. Many indicated that they had initially tried the directional mode in adverse listening situations after receiving their hearing aids but had not noticed any improvement in their ability to understand speech. As a result, they simply left their hearing aids set in the default omnidirectional mode in all listening environments.

Obviously, it would be useful to identify listener variables that could be measured during the initial hearing aid evaluation to determine whether a patient is likely to be a successful user of directional microphone technology. Not only would such information be useful in determining candidacy for directional microphones, it could assist considerably in the counseling of patients fit with this technology to create realistic expectations of the benefit that may be expected in everyday listening. Because there is substantial variability in the benefit obtained from directional microphones, both in the test booth and in everyday living, one might hypothesize

that the directional advantage measured in the clinic may relate to benefit from directional microphones in everyday listening situations. It seems reasonable, for example, to assume that an individual who obtains no directional advantage under laboratory test conditions would realize little or no benefit in real-world listening situations. This investigation examined the extent to which a clinical measure of the directional advantage, as well as other audiological and demographic variables that can be obtained at the time a patient is evaluated for directional microphone hearing aids, can predict success with this technology in everyday life.

## METHOD

### Participants

Participants were recruited from the hearing-impaired patient population of the Army Audiology and Speech Center (AASC). All had been fit with binaural manually switchable omnidirectional/directional microphone hearing aids a minimum of six months but not more than two years prior to enrollment. Participants must have reported that they were wearing their hearing aids at least four hours each day, that their hearing aids were in good working order, and that they understood how to use the different programs of their hearing aids. Potential participants were identified through a review of outpatient medical records of the AASC. Individuals were contacted, in the order in which they were identified, by one of the investigators via a telephone call for a brief interview. Any patients who reported problems or complaints about their hearing aids were referred to their audiologist for follow-up and were not invited to participate in the study. Two participant groups were recruited. The first consisted of patients who reported that they regularly used each microphone mode ("successful users"). To be included in this group, the individual must have reported that she or he used each microphone mode a minimum of ten percent of the time. The second group consisted of patients who reported not using the

directional microphone mode; that is, they left their hearing aids in the default omnidirectional mode all of the time (“unsuccessful users”). The first 20 individuals (10 in each group) who met the inclusion criteria and agreed to participate constituted the subject sample for this study. Although participants were not excluded based on gender, all participants were male, reflecting the demographics of the AASC patient population.

**Hearing Aids**

Participants wore a number of different hearing aid makes and models, all featuring manually switchable omnidirectional/directional microphones. Devices were fit and fine-tuned by experienced clinical audiologists following manufacturer-recommended procedures. Five participants had hearing aids requiring a remote control to change programs, whereas the remaining 15 participants had a push-button or toggle switch control on the hearing aids themselves.

Twelve of the 20 participants had been fit with in-the-ear style hearing aids, whereas eight participants wore behind-the-ear instruments. Six participants in the successful group and two participants in the unsuccessful group had hearing aids featuring adaptive directionality. The remaining subjects had fixed hypercardioid polar responses. Three participants in each group were wearing hearing aids in which the directional microphones had been fully equalized to compensate for the low-frequency roll-off inherent in directional microphones. The remaining participants’ directional microphones were not equalized. Information regarding the individual participants’ hearing aids can be seen in Table 1.

**PROCEDURES**

Participation in the study involved a single visit during which all data were collected. An audiological evaluation was conducted to document the participant’s current hearing. This included air- and bone-

**Table 1. Hearing Aid Information for Individual Participants**

Participant	HA Style	HA Type	Polar Pattern	Equalized Frequency Response?	Participant	HA Style	HA Type	Polar Pattern	Equalized Frequency Response?
Successful					Unsuccessful				
1	BTE	Digital	Adaptive	No	11	ITE	Digital	Fixed Hypercardioid	No
2	BTE	Digital	Adaptive	Yes	12	ITE	Analog	Fixed Hypercardioid	No
3	BTE	Digital	Adaptive	Yes	13	HS	Analog	Fixed Hypercardioid	No
4	HS	Analog	Fixed Hypercardioid	No	14	BTE	Digital	Adaptive	Yes
5	BTE	Digital	Adaptive	No	15	HS	Analog	Fixed Hypercardioid	Yes
6	BTE	Digital	Adaptive	No	16	BTE	Digital	Adaptive	Yes
7	ITE	Analog	Fixed Hypercardioid	Yes	17	HS	Analog	Fixed Hypercardioid	No
8	HS	Analog	Fixed Hypercardioid	No	18	ITE	Analog	Fixed Hypercardioid	No
9	Canal	Analog	Fixed Hypercardioid	No	19	HS	Analog	Fixed Hypercardioid	No
10	BTE	Digital	Adaptive	No	20	ITE	Analog	Fixed Hypercardioid	Yes

Note: HA = hearing aid; BTE = behind-the-ear; ITE = full-shell in-the-ear hearing aid; HS = half-shell in-the-ear hearing aid

conduction pure-tone thresholds, and unaided word recognition (NU-6) at a comfortable listening level. Following the audiological evaluation, participants were asked to access each mode of their hearing aids (omnidirectional and directional) to assure that they understood how their hearing aids worked and that they had adequate manual dexterity to manipulate the devices. A listening check was performed on each hearing aid to verify the program number or switch setting that activated each microphone mode, as well as to rule out any obvious malfunctions. Additionally, 2 cc-coupler gain measurements were made of each hearing aid in both the omnidirectional and the directional mode at the user's volume control setting. These measurements were made to determine whether there were differences in hearing aid gain between the two subject groups for each microphone mode. The hearing aids were positioned in a Fonix 6500 test box so that the front microphone directly faced the test signal. Measurements were made using a 65 dB SPL composite test signal. Noise reduction algorithms, when present, were deactivated for this testing

### Hearing in Noise Test (HINT)

A commercially available compact disc recording of the HINT (Nilsson et al, 1994) was used to assess speech recognition ability for each microphone mode. One practice list was administered before actual testing began. Three 20-sentence lists were presented to determine the SNR for 50 percent correct recognition for each microphone mode. The resulting three scores were averaged for each microphone mode. The two averages were taken as the overall HINT scores for the two microphone modes, from which the directional advantage was calculated for each participant. The order of testing of the omnidirectional and the directional programs was randomized across participants in each group. Directional advantage was taken as the omnidirectional HINT score minus the directional HINT score.

Testing was performed in a 3.0 m by 2.5 m sound-treated audiometric test suite. The recommended calibration procedures for the HINT were used with the sound level meter microphone placed at the location of the

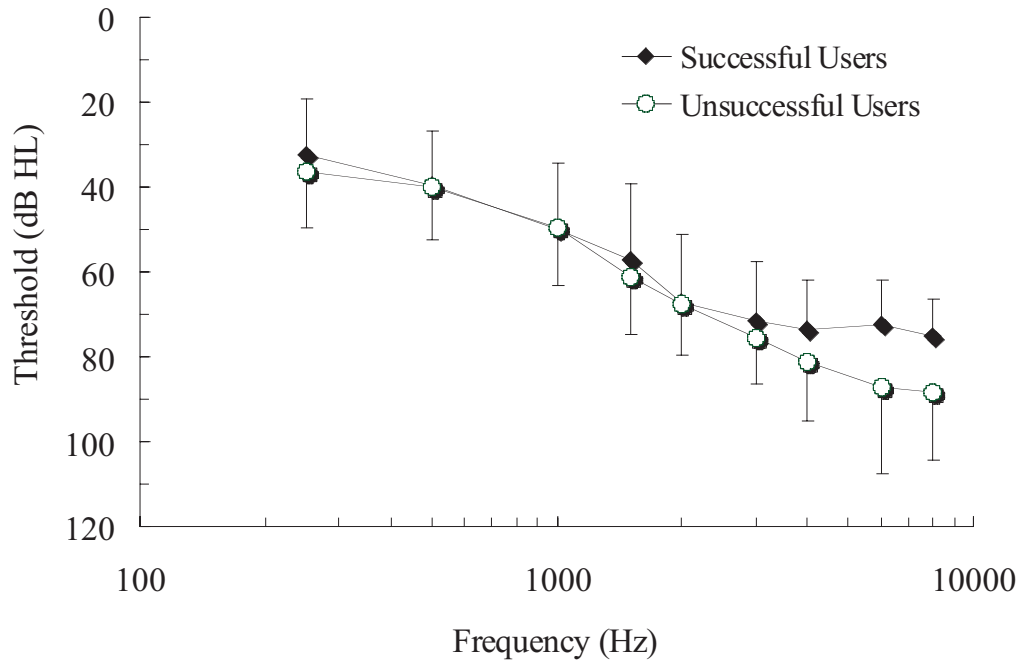
center of the listener's head with the listener absent. Test materials were presented to the participant in the sound field with the test sentences presented through a wall-mounted loudspeaker (B&W model LM-1) positioned at 0 degrees azimuth and correlated competing noise coming from three wall-mounted loudspeakers (Rock Solid) positioned at 90, 180, and 270 degrees azimuths. The front and rear loudspeakers were each 120 cm, and each side speaker was 95 cm from the center of the participant's head. All loudspeakers were positioned at ear level, and the listener was seated in the exact center of the test room.

### Listening Situations Survey (LSS)

Participants completed the Listening Situations Survey (LSS), a four-item questionnaire developed for use in this study. The LSS was used to assess the frequency with which participants encountered listening situations in daily living in which background noise is likely to be a problem. The LSS was intended to determine if successful and unsuccessful users of directional microphones tend to encounter such listening situations with similar frequency in everyday living. The four items were:

1. On average, how often are you in listening situations in which bothersome background noise is present?
2. How often are you in social situations in which at least three other people are present?
3. How often are you in meetings (community, religious, work, classroom, etc.)?
4. How often are you talking with someone in a restaurant or dining hall setting?

Participants selected one of eight response choices for each item: "More than four times a day," "Three or four times a day," "Once or twice a day," "Three or four times a week," "Once or twice a week," "Once or twice a month," "Once or twice a year," "Never." The items of the questionnaire and the response categories were selected based on the results of Cord et al (2002) and Surr et al (2002).



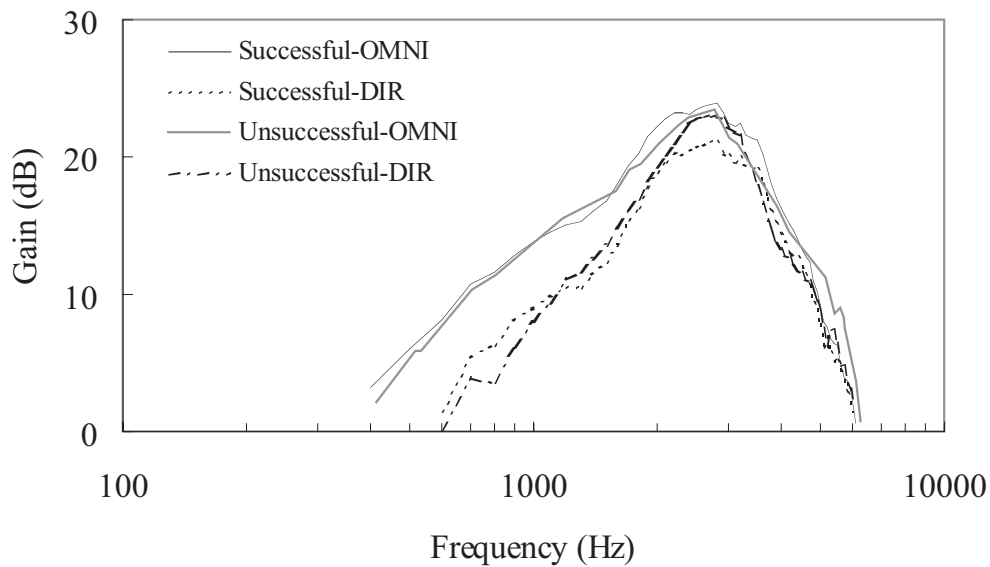
**Figure 1.** Mean audiometric data, collapsed across right and left ears, for the two groups of participants. The error bars in this and subsequent figures indicate 1 SD.

**RESULTS**

**Audiometric and Demographic Data**

Figure 1 displays the mean audiogram averaged across left and right ears for each group of participants (successful users and

unsuccessful users). The thresholds for the two groups were compared at octave and half-octave frequencies (250 to 8000 Hz) using analysis of variance. The results revealed a significant main effect for group [ $F(1,8) = 8.2, p = .02$ ]. T-tests at individual frequencies revealed significant differences between the two groups for only two test frequencies, 6000



**Figure 2.** Mean 2-cc coupler gain measures for each microphone configuration for each group of participants. OMNI = omnidirectional microphone; DIR = directional microphone.



**Table 2. Audiological and Demographic Information for Individual Participants**

Participant	Age	Successful				Unsuccessful					
		Unaided PTA	Unaided WR	Hrs. HA Use/Day	Experience with Current HAs (months)	Unaided PTA	Unaided WR	Hrs. HA Use/Day	Experience with Current HAs (months)		
1	73	56	80	18	12	11	72	62	100	16	22
2	72	56	81	16	12	12	78	44	96	15	24
3	73	55	82	6	12	13	76	39	86	16	9
4	71	46	92	4	12	14	79	71	49	12	24
5	73	48	73	15	12	15	71	43	94	16	12
6	79	59	72	12	12	16	76	53	74	10	12
7	80	57	69	12	10	17	78	57	38	12	11
8	83	30	95	4	11	18	83	47	87	12	22
9	68	53	96	14	10	19	70	45	96	12	13
10	73	63	44	16	21	20	82	64	70	16	12
Mean	74.5	52.3	78.4	11.7	12.4	Mean	76.5	52.3	79.0	13.7	16.1
SD	4.6	9.3	15.4	5.2	9.3	SD	4.4	10.6	21.3	2.3	6.1

Note: PTA = pure-tone average (.5, 1, and 2 kHz); WR = word recognition; HA = hearing aid. PTA and WR were averaged across left and right ears for each participant.

Hz ( $t = -2.40$ ,  $p = .03$ ) and 8000 Hz ( $t = -2.50$ ,  $p = .02$ ), with the unsuccessful users having slightly poorer threshold sensitivity in the higher frequencies than the successful users. Demographic and additional audiometric data for the participants in each group are given in Table 2. T-tests revealed no significant differences between the two groups for age ( $t = .99$ ,  $p = .34$ ), unaided SRT ( $t = .04$ ,  $p = .96$ ), unaided word-recognition scores ( $t = .07$ ,  $p = .94$ ), hours of daily hearing aid use ( $t = 1.11$ ,  $p = .29$ ), or length of experience with current hearing aids ( $t = -1.71$ ,  $p = .10$ ).

### Hearing Aid Test Box Measures

Figure 2 shows the mean 2-cc coupler gain, averaged across right and left ears, for each microphone configuration and participant group. Similar average gain was observed for both the omnidirectional and directional modes, as well as similar amounts of low-frequency roll-off in the directional mode for both groups. The coupler gain for the two groups was compared at octave and half-octave frequencies (500 to 8000 Hz) using analysis of variance. The results revealed no significant difference between the two groups for either the omnidirectional [ $F(1,7) = .01$ ,

$p = .91$ ] or the directional mode [ $F(1,7) = .15$ ,  $p = .70$ ].

### HINT Directional Advantage

The mean directional advantage across all 20 participants in this study was 2.7 dB (range: -3.4 to 10.5). For the successful users, the mean directional advantage was 3.2 dB (SD: 2.4, range: -0.8 to 6.0), and for the unsuccessful users was 2.1 dB (SD: 3.9, range: -3.4 to 10.5). Although the successful users obtained a slightly greater mean directional advantage than the unsuccessful users, this difference was not statistically significant ( $t = .79$ ,  $p = .44$ ).

Table 3 shows the individual directional advantage scores for the participants in each group. Also displayed are the individual omnidirectional and directional performance scores from which the directional advantage for each participant was derived. Clearly, there was a great deal of variability within both groups. Three of the ten successful users obtained little or no directional advantage in the sound booth, whereas seven of the ten unsuccessful users obtained a positive directional advantage despite reporting no perceptible advantage for the directional

**Table 3. HINT Results for Individual Participants**

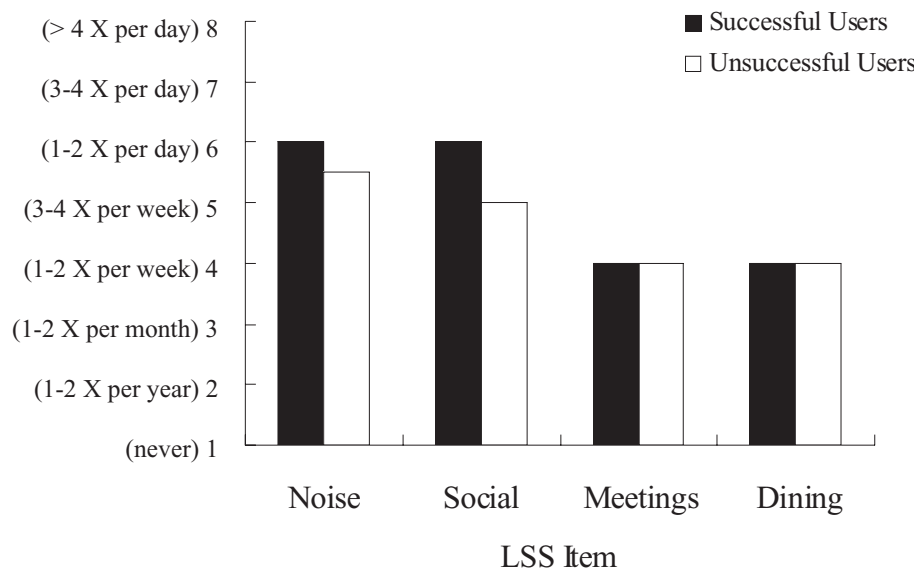
Participant	OMNI	DIR	DA	Participant	OMNI	DIR	DA
Successful				Unsuccessful			
1	1.27	-2.83	4.10	11	-4.63	-7.23	2.60
2	0.23	-4.23	4.47	12	1.03	-0.10	1.13
3	4.57	-1.43	6.00	13	-1.63	1.80	-3.43
4	-2.20	-5.50	3.30	14	12.10	1.63	10.47
5	2.83	-2.13	4.97	15	-3.77	-7.50	3.73
6	-0.17	-5.47	5.30	16	4.13	0.37	3.77
7	2.83	-1.73	4.57	17	3.23	5.77	-2.53
8	-3.40	-4.23	0.83	18	-1.10	-2.90	1.80
9	-3.70	-3.27	-0.43	19	-2.27	-2.33	0.07
10	3.07	3.83	-0.77	20	1.50	-1.80	3.30
Mean	0.53	-2.70	3.23	Mean	0.86	-1.23	2.09
SD	2.89	2.71	2.45	SD	4.88	4.08	3.86

Note: OMNI = omnidirectional performance score; DIR = directional performance score; DA= directional advantage score

mode in their everyday lives. Further, the individual receiving the largest directional advantage in the test booth (participant #14) was in the unsuccessful group. It should be noted that, even with this participant's data deleted from the analysis, the difference between the mean directional advantages for the two participant groups did not achieve statistical significance.

**LSS Results**

Figure 3 displays the median LSS ratings for each group. Successful users of directional microphone hearing aids, on average, reported that they were somewhat more likely than the unsuccessful users to encounter listening situations in which bothersome background noise was present, and to encounter more social situations in which at least three other people were present. However, a Mann-



**Figure 3.** Median LSS values for each group.



Whitney U test revealed no statistically significant difference between the two groups for any of the four items.

## DISCUSSION

The mean directional advantage (across all 20 participants) of 2.7 dB observed in this study is in substantial agreement with Walden et al (2004), who used similar testing materials and procedures to those used in this study. Walden et al obtained a mean directional advantage of 3.3 dB for 17 participants approximately five weeks after they had been fitted with a switchable omnidirectional/directional hearing aid. Although comparable results were obtained in the two studies from this laboratory, the mean directional advantage obtained in these studies is substantially less than that reported by Valente et al (1995) and by Agnew and Block (1997), who reported mean directional advantages of 7.6 dB and 7.5 dB respectively. The discrepancy in results among these studies is likely due to methodological differences. Specifically, Valente et al and Agnew and Block both used only a single loudspeaker to deliver the competing background noise, which was positioned at 180 degrees azimuth. Such an arrangement will generally provide a larger directional advantage than the three loudspeaker arrangement used in this study (Ricketts, 2000b).

Although most participants obtained a directional advantage in the test booth, the magnitude of directional advantage did not predict success with directional microphones in everyday life; that is, the mean directional advantage obtained in the test booth did not differ significantly between patients who used the directional mode regularly and those who reported little or no benefit from directional microphones in daily living. Notably, the majority of unsuccessful users obtained some directional advantage in the test booth. However, this advantage did not translate into a perceptible benefit to the patient.

One possible explanation for this finding is that, notwithstanding the LSS results, the listening situations typically encountered by these patients in everyday life are not ones in which the directional mode will provide advantage over the omnidirectional mode.

Recent studies (Cord et al, 2002; Surr et al, 2002; Walden et al, 2004) suggest that benefit from directional microphones is highly dependent upon the characteristics of the listening environment. Only when a specific set of environmental conditions exists do patients express a distinct preference for the directional mode. Generally, directional microphone use is favored in listening situations in which the signal source is relatively close to and in front of the listener, there is spatial separation of signal and noise sources, and reverberation is relatively low. Patients who rarely encounter these types of listening situations will have little opportunity to realize the advantages of directional microphones and, therefore, will perceive little benefit from this technology. Although only relatively small group differences were observed for the LSS ratings, the items of this questionnaire described very general types of listening situations, which may not have captured the specific environmental characteristics that favor directional processing.

It is also possible that some patients in the unsuccessful group had unrealistically high expectations regarding how much directional microphones would improve their ability to understand speech in everyday noisy listening situations. In this regard, Walden et al (2000) observed that the benefit obtained from directional microphones in everyday living is substantially less than that which might be expected based on the directional advantage obtained in a test booth. Further, Surr et al (2002) reported that hearing aid users do not notice significant performance differences between omnidirectional and directional microphones in most listening situations encountered in daily life. In the situations where performance differences are noted, the differences often tend to be subtle. It is possible that some of these patients stopped using the directional mode because they expected dramatically improved speech understanding in background noise from the directional microphones, rather than the subtle differences that are more typical of everyday listening. Nevertheless, the results of Cord et al (2002) suggest that patients who persist in experimenting with the directional microphone mode eventually determine when it will be of benefit and set their hearing aids in that mode when appropriate.

Perhaps somewhat surprisingly, three of the successful users who reported benefit from using the directional microphone mode in their daily living obtained little or no directional advantage in the test booth. Assuming the reliability of the laboratory testing and the participants' judgments of the benefit of the directional mode in their everyday lives, some explanation, other than a directional advantage, must explain their successful use of directional microphones. One possibility is a difference in overall output between the two microphone modes. Due to the normal low-frequency roll-off, the overall output of a hearing aid will be lower in the directional mode than in the omnidirectional mode (Ricketts, 2001). For seven of the ten participants in each group, no compensation for the low-frequency roll-off was used when fitting their hearing aids. Additionally, the nulls introduced in the polar response by the directional microphones can create a perceptible change in loudness when the directional mode is activated in background noise, even with a low-frequency boost. Hence, output level is generally lower in the directional mode than the omnidirectional mode, with comparable input levels. It may be that, for some successful users of directional microphone hearing aids, reduction of annoying sounds and greater listening comfort resulting from the reduced output in the directional mode is perceived as beneficial, even if speech understanding in noise is not improved. Of course, the reduced output in the directional mode can have the opposite effect for other patients who may sense that there is insufficient output in the directional mode. To this point, when asked why they were not using the directional mode, four of the ten unsuccessful users stated that the directional mode reduced the volume of all sounds too much, including the signal they wanted to hear, whereas the remaining six unsuccessful users stated that it did not help them to hear in noise. Ricketts and Henry (2003) suggest that individuals with low-frequency hearing loss of greater than 40 dB HL will benefit from low-frequency gain compensation, whereas those with thresholds of 40 dB HL or better should obtain little or no advantage. Examination of the audiograms of the four participants in the current study who reported an unacceptable reduction of volume in the directional mode reveals that all four

had low-frequency thresholds of 40 dB HL or better, suggesting that equalization of the frequency responses for these participants may not have resulted in significant improvement in directional advantage measures and/or changes in the amount of success in everyday listening with directional microphones. However, because the influence of possible volume differences on participants' success with directional microphones was not investigated systematically, this issue requires additional study.

It should be noted that two participants in each group actually obtained a negative directional advantage in the test booth. In clinical practice, measures of directional advantage in the sound booth are commonly used to demonstrate and verify the function of directional microphones. The assumption is that measures of directional advantage reflect the differences between the electroacoustic characteristics of the omnidirectional and directional microphone modes (Ricketts and Mueller, 1999; Ricketts et al, 2001). Because of the clinical nature of the study, no direct measures of directivity were available to verify that the directional mode of the participants' hearing aids was functioning optimally. Listening checks suggested that they were operating properly in every case. Nevertheless, because the directionality of the hearing aids was not verified by electroacoustic measurements, the actual amount of directivity being provided by each instrument is unknown. Therefore, it cannot be ruled out that some of the variability in the directional advantage observed in the test booth and experienced by the participants in everyday use may be related to poor directivity in the directional mode.

Other factors may also have contributed to the variability in the directional advantage obtained by the participants in the test booth. Ricketts (2000a) demonstrated that factors such as vent size and the alignment of microphone ports can affect directional advantage measures. Ricketts (2000b) also observed that the magnitude of directional advantage can vary across hearing aid models and can vary interactively with the test environment. Recall that a variety of hearing aid makes and models were represented in this study. Although these factors may have contributed to the variability in the directional advantage obtained by the

participants in the test booth, they probably do not explain why the directional advantage did not appear closely related to success with directional microphones in everyday living.

Although the majority of participants had been fitted with directional microphones having a fixed hypercardioid polar response, six of the successful users, but only two of the unsuccessful users, had hearing aids that incorporated adaptive directionality. Hearing aids with adaptive directionality are intended to monitor the listening environment to determine the location of the most intense sound source from the sides or behind the listener and automatically adjust the polar response of the microphone to provide maximum attenuation for sounds from that location. Adaptive directionality has been shown to provide certain performance advantages over a fixed polar response under specific laboratory test conditions (Ricketts and Henry, 2002; Oberzut and Olson, 2003). However, little is known regarding whether this advantage in a controlled test booth environment translates into a performance advantage for adaptive directionality in everyday listening situations. This study provides some evidence to suggest that patients wearing adaptive directionality may be more likely to be successful with directional microphone hearing aids in everyday living than patients fit with a fixed polar response. However, this issue requires more systematic investigation.

## CONCLUSIONS

Although directional advantage measured in a test booth and everyday success with directional microphones both vary widely across hearing-impaired patients, there does not appear to be a close relationship between these two variables. Small, but statistically nonsignificant, differences were observed between successful and unsuccessful users of directional microphone hearing aids for mean directional advantage and for the frequency with which noisy listening situations are encountered in everyday living. The magnitude of these group differences does not allow prediction of success with directional technology for individual patients.

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