CHAPTER SEVENTEEN

Optimization of Amplification for Deaf-Blind Children

Anne Marie Tharpe, Daniel H. Ashmead, Todd A. Ricketts, Ann M. Rothpletz and Robert Wall

Introduction

It is often assumed that individuals with dual hearing and vision impairments rely more heavily on their hearing than those with hearing impairment alone and, thus, would welcome the use of amplification when indicated. After all, the majority of this population has some degree of residual hearing ability (Michael and Paul 1990). A recent survey of clinical audiologists confirmed the belief that those with vision and hearing difficulties could potentially benefit more from amplification than those with hearing loss alone (Tharpe 2000). However, we have been cautioned to keep in mind that amplification for those with dual impairments has a role beyond that of only enhancing speech perception ability (Wiener and Lawson 1997). Amplification can also enhance orientation and mobility skills by helping to identify one's location relative to environmental features and to move safely through one's environment. These skills are essential to the development of successful independent living skills.

Much research has been conducted on hearing instrument specifications designed to enhance speech perception ability, but considerably less exists on enhancing the detection of environmental auditory cues. It is unknown whether there is a combination of hearing instrument characteristics that can be used to enhance speech perception and also improve detection of environmental cues or possibly affect one or the other adversely. The need for an integrated approach is apparent for children with dual sensory impairments who need to coordinate the aspects of guiding, route instruction, and verbal communication. Even the limited research that has been done on sound localization with hearing instruments has not considered the specific spatial hearing needs of persons with visual impairments.

In recent years there has been strong emphasis on hearing instruments that enhance speech perception by selectively emphasizing sounds coming from directly in front of the listener. This is accomplished by several strategies for modifying the directional sensitivity of the microphone in the hearing instrument. This directional emphasis enhances speech recognition (Ricketts and Dhar 1999), but its effects on spatial hearing as related to orientation and mobility are not known. A second dimension of hearing instrument configuration that is of interest to this population is the degree of low frequency emphasis. As speech recognition is based mostly on frequencies above 500 Hz, it is common for hearing instruments to attenuate frequencies below a cutoff level in the range of 500 to 1000 Hz. This low frequency cutoff is designed to reduce background sounds that may interfere with speech perception. However, that low-frequency range contains critical information for orientation and mobility with respect to traffic sounds (Wiener et al. 1977) and environmental surfaces such as walls (Ashmead et al. 1998). A third important property of hearing instruments is the flexibility to switch between different configurations. That is, hearing instruments that are programmable can be set to run in several different configurations. Assuming that different listening situations require different hearing instrument settings for optimal perception, this flexibility will be important to consider in rehabilitation strategies for those with vision and hearing impairments.

Extant research literature is rather sparse with respect to specific factors that can enhance both communication and independent mobility in

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Address correspondence to: Anne Marie Tharpe, Ph.D., Vanderbilt Bill Wilkerson Center, 1114 19th Avenue South, Nashville, TN, USA 37212

individuals with dual sensory impairments. The purpose of the research described herein was to investigate specific hearing instrument features that would be likely to have an impact on orientation and mobility as well as speech perception. Specifically, we examined the use of directional and omnidirectional microphones, and frequency shaping with and without added low frequency emphasis on the outcome of speech perception and orientation and mobility tasks.

Method

Participants

Seven adults (mean age = 52.1 years) and four children (mean age = 12.5 years) with significant hearing and vision deficits were enrolled in this study. Visual acuity ranged from 20/200 to light perception only, or severely restricted peripheral vision. Hearing ability averaged 52.75 dB in the better hearing ear (pure tone average at .5, 1.0, and 2.0 kHz). All participants were oral communicators. Because of the nature of our orientation and mobility tasks, we excluded individuals with concomitant physical or cognitive impairment that would preclude their ability to follow directions.

Procedures

Participants were assessed on a speech perception task and a variety of orientation and mobility tasks while wearing hearing instruments with different combinations of characteristics (directional versus omnidirectional microphone, and low-frequency emphasis versus low-frequency reduction shaping). The hearing instruments used were the Phonak PICS-2 programmable instruments with AudioZoom technology. AudioZoom allows the user to switch, via a digital remote control, between directional and omnidirectional microphone use. Hearing instruments were fitted binaurally, utilizing the Desired Sensation Level (DSL) prescriptive approach (Seewald, Ramji, Sinclair, Moodie and Jamieson 1996) and probe microphone measures for verification. Linear amplification with soft peak clipping output limitation was used across all subjects in order to eliminate potential confounding interactions with compression amplification. In order to examine the potential effects of low frequency amplification, a "modified DSL" configuration was also utilized. The modified DSL refers to the automatic decrease in low frequency amplification resulting from activating the directional microphone option. That is, the hearing instrument was fitted to DSL targets with the omnidirectional microphone. When the directional microphone was enacted, the settings were not adjusted to compensate for the subsequent decrease in low frequency amplification. Therefore, there were two microphone conditions (directional and omnidirectional) and two frequency response conditions (DSL and modified DSL) for a total of four hearing instrument configurations (directional mic + DSL, directional mic + modified DSL, omnidirectional mic + DSL, and omnidirectional mic + modified DSL). Figure 1 illustrates the average deviation from the DSL targets. A number of recent studies have shown that listeners with profound, high frequency, hearing thresholds often reveal little or no benefit when provided with "appropriate" high frequency amplification (e.g., Moore, Huss, Vickers, Glasberg and Alcántara 2000; Ching, Dillon and Byrne 1998). As a result of these issues and potential feedback problems, the magnitude of high frequency amplification was reduced for the few subjects who presented profound, high frequency, hearing loss as reflected in figure 1. This figure also reveals similar real-ear-insertion gain (REIG) for the directional and omnidirectional conditions (either the pair of "modified-DSL" or the pair of "DSL"), as intended. Each participant completed the test battery for each hearing instrument condition.

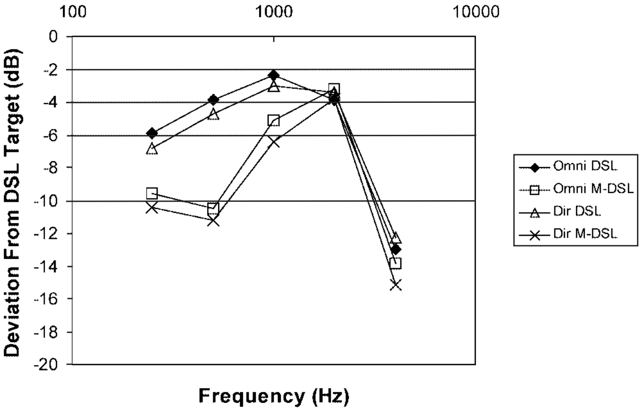

Figure 1. Average real-ear-insertion gain (REIG) for participants with each hearing instrument configuration (omnidirectional microphone with modified Desired Sensation Level [DSL] fitting, omnidirectional microphone with DSL fitting, directional microphone with modified DSL fitting, and directional microphone with DSL fitting).

Speech Perception Task

Lists from the Hearing in Noise Test (HINT; Nilsson, Soli and Sullivan 1994) and Hearing in Noise Test for Children (HINT-C; Gelnett, Suminda, Nilsson and Soli 1995) were presented via loudspeaker (at 0° azimuth) in a background of noise (at 180° azimuth). The participant's task was to repeat the sentences spoken by a male talker in the presence of noise presented at a fixed level (65 dBA SPL). Correct identification of each sentence was based on proper repetition of key words as specified in the test manual. Scoring was accomplished for two, 10-sentence blocks. A reception threshold for sentences (RTS) was calculated as the signal-to-noise ratio necessary to achieve 50% correct performance. Presentation level of the sentences was adaptively adjusted depending on the participant's response (an incorrect response raised the level, and a correct response lowered the speech level for the next presentation). The level of the sentence stimuli was varied in 4 dB (first 5 trials) and 2 dB steps (all remaining trials).

Orientation and Mobility Tasks

The assessment methods used in the area of orientation and mobility were those specifically related to the role of hearing. Participants were blindfolded for all orientation and mobility tasks in order to eliminate the influence of varying levels of visual ability.

Use of traffic sounds to align for street crossing. Participants were brought to a sidewalk alongside a 2-lane roadway where one had a clear line of hearing for over 30 meters in both directions. Vehicles on the roadway traveled at speeds around 50 km per hour at the point at which they passed in front of the participant's position. Participants were positioned on the sidewalk, one meter from the near lane of the roadway and asked to line up perpendicularly, as though about to cross the street directly to the other side. Prior to each of the six alignment trials, participants were rotated to a random angle. Participants were then free to line up while listening to traffic sounds for a minute or so and were allowed to use the sounds from as many passing vehicles as they needed to fine tune their alignment. Errors were measured from a belt-mounted compass. The criterion direction for good alignment was based on the mean of 4 compass settings taken when the participant was positioned by the experimenter. An absolute error score was computed by averaging the absolute values of the misalignment across the six trials.

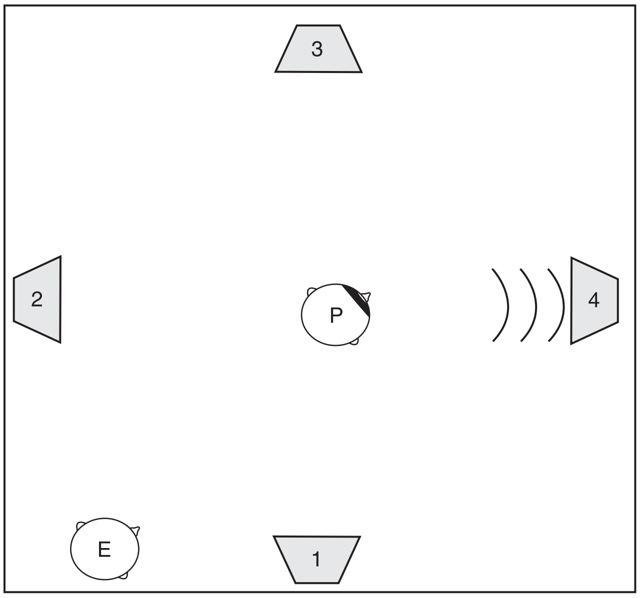

Figure 2. Room layout for localization task. In this example, the blindfolded participant (P) is headed toward speaker 4 as the experimenter (E) observes out of the way of the speakers.

Localization task. Figure 2 illustrates the room design for the localization task. Note that four speakers were located at equal distance (1.25 meters) from the participant who was positioned in the center of the room. For each trial, the signal could emanate from any of the four speakers, and the participant was headed in one of four directions. For example, a heading of 0° azimuth meant that the subject was positioned within approximately 20° of either side of the active speaker before the signal was emitted. There were four trials from each speaker, one for each heading, for a total of 16 trials. The signal was pink noise and was emitted for 1 second. The participant's task was to turn and face the direction of the signal as closely as possible. Each participant wore a compass for purposes of recording his or her alignment to the speakers. Prior to data collection, the participant was aligned by the experimenter directly in front of each speaker two times. An average of these two measures served as the criterion direction for measuring errors for this task. Average absolute errors were calculated for the different listener positions relative to the sound source (0° or straight ahead, 180° or straight behind, and 90° to the left or right).

Wall-walking task. The purpose of this task was to determine if the participants could use the environmental acoustic effects to walk parallel between two walls without making contact. Participants were asked to walk (without a cane and without touching the walls) along a long 3-foot-wide hallway, maintaining a path parallel to the walls. Five trials were completed per hearing instrument condition. Error scores were the average number of contacts made with the wall across the five trials.

Results and Discussion

Speech Perception

The results obtained from the HINT are represented in figure 3. Recall that the dependent variable for this task was the reception threshold for sentences (RTS) and the lower the RTS, the better the performance. As noted in this figure, performance in the unaided condition was poorer than all aided conditions and performance with the omnidirectional microphone was poorer than with the directional microphone. An ANOVA revealed a significant main effect of microphone type, $F(1,10) = 16.77$, $p = .002$. There was no significant main effect of frequency shaping and no significant interaction. In planned analytical comparisons, the directional modified-DSL condition yielded significantly better performance than either of the omnidirectional microphone conditions (i.e., DSL or modified DSL), $F(1,10) = 15.81$, $p = .000$ and $F(1,10) = 8.50$, $p = .01$, respectively. In addition, the directional DSL condition yielded significantly better performance than the omnidirectional DSL condition, $F(1,10) = 7.66$, $p = .02$. There was no significant effect of the frequency shaping (that is, the modified versus standard DSL). The other pairwise comparisons were not significant. These results confirm those of many others that directional microphones are of considerable benefit when listening in the presence of background noise (Gravel, Fausel, Liskow and Chobot 1999; Pumford, Seewald, Scollie and Jenstad 2000; Ricketts, Lindley and Henry 2001).

Orientation and Mobility Tasks

Use of traffic sounds to align for street crossing. Figure 4 displays the results from the street-alignment task. Note that the error rate was high (approximately 35° to 45° of error) across all conditions, aided and unaided. An ANOVA yielded no significant main effects of microphone type or frequency shaping, and no significant interactions. Insofar as there were differences (albeit statistically non-significant), the omnidirectional microphone conditions yielded better performance than the directional microphone conditions. Overall, the participants performed very poorly regardless of hearing instrument condition. Previous studies on this task with sighted and blind individuals revealed error rates of only 5 to

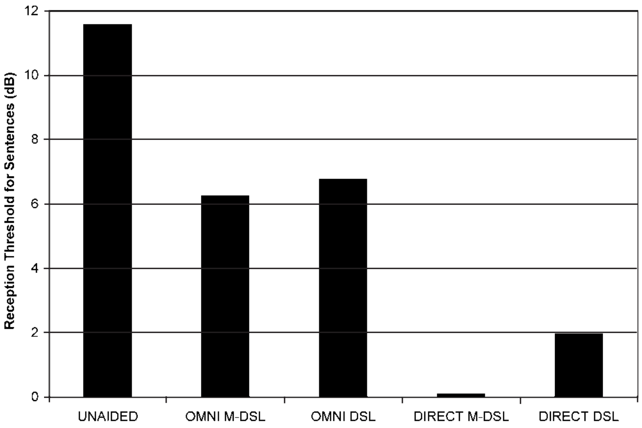

Figure 3. HINT performance as a function of hearing instrument configuration (unaided, omnidirectional microphone with modified Desired Sensation Level [DSL] fitting, omnidirectional microphone with DSL fitting, directional microphone with modified DSL fitting, and directional microphone with DSL fitting).

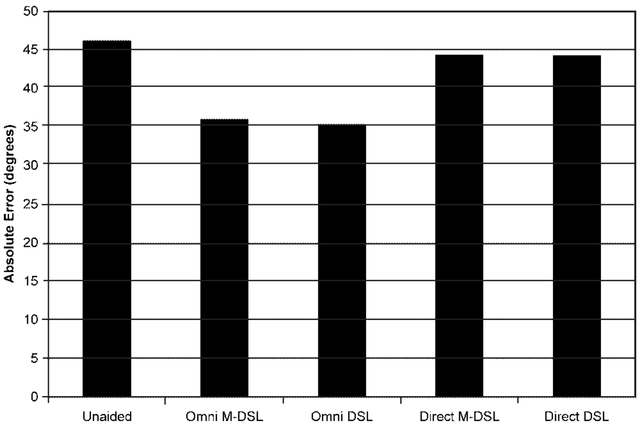

Figure 4. Street Alignment task performance as a function of hearing instrument configuration (unaided, omnidirectional microphone with modified Desired Sensation Level [DSL] fitting, omnidirectional microphone with DSL fitting, directional microphone with modified DSL fitting, and directional microphone with DSL fitting).

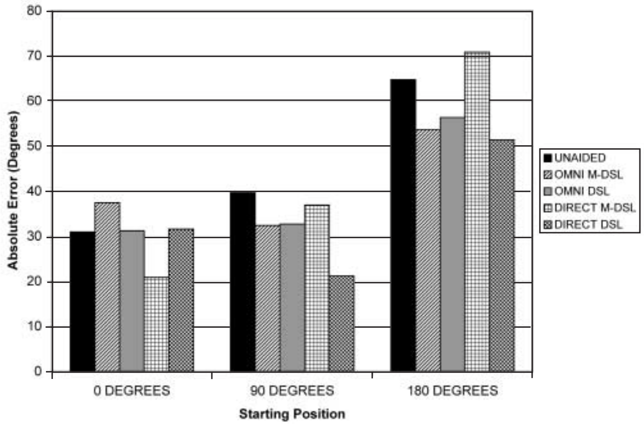

Figure 5. Localization task performance as a function of heading and hearing instrument configuration (unaided, omnidirectional microphone with modified Desired Sensation Level [DSL] fitting, omnidirectional microphone with DSL fitting, directional microphone with modified DSL fitting, and directional microphone with DSL fitting).

20° (Guth, Hill and Rieser 1989). This poor performance by participants in the present study may reflect a lack of practice at independent street crossing, or a deficit in auditory motion perception.

Localization task. Results of the localization task are displayed in figure 5. Not unexpectedly, the error rate was highest for the 180° heading (when the sound source was behind the listener) across all hearing instrument configurations. A repeated measures ANOVA yielded a significant main effect of heading (i.e., 0°, 90° right, 90° left, 180°), $F(3,30) = 11.48$, $p = .00$, and a significant hearing instrument condition x heading interaction , $F(12,120) = 2.23$, $p = .01$. The main effect of hearing instrument condition was non-significant. Examination of the frequency-shaping factor (DSL versus modified DSL) collapsed across microphone type, yielded no significant differences across headings. As depicted in figure 6, examination of microphone type (directional versus omnidirectional) collapsed across frequency shaping, showed a significantly better performance with the directional than the omnidirectional microphone with the 0° heading, $F(1,10) = 6.26$, $p = .03$, and significantly better performance with the omnidirectional than the directional microphone in the 180° heading, $F(1,10), = 6.6, p = .03$. Effect of microphone type in the 90° heading was not significant. One must assume that the enhanced localization ability with the omnidirectional microphone in 180° heading is the result of reduced audibility of the signal because of the suppression of sounds emanating from behind with a directional microphone.

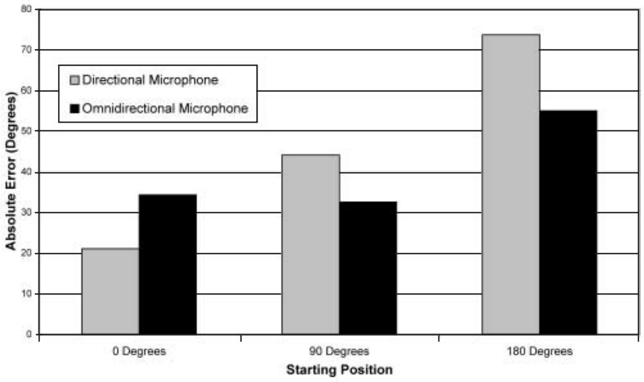

Figure 6. Localization task performance as a function of heading and hearing instrument microphone type.

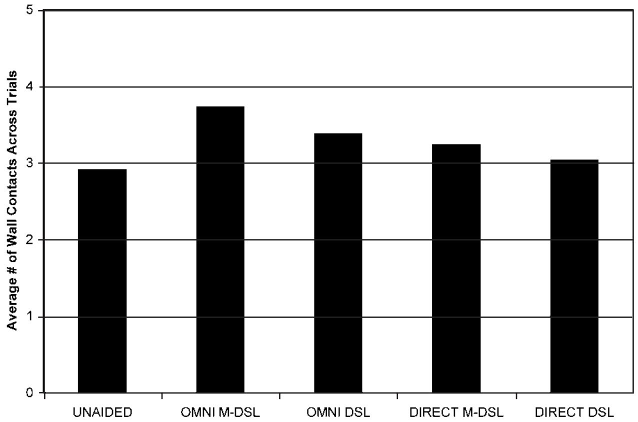

Figure 7. Wall-walking task performance as a function of hearing instrument configuration.

Wall-walking task. Recall that the dependent variable for the wall-walking task was the number of times that the subject bumped one side of the wall or the other while attempting to walk along the wall without making contact. Note in figure 7 that, on average, between three and four contacts with the wall were made by the participants for all aided conditions. An ANOVA revealed no significant differences in performance on this task across hearing instrument conditions. This level of performance is considerably worse than has been reported for children who have visual impairments but good hearing (Ashmead et al. 1998).

There may be a couple of explanations for the overall poor performance reported for the wall-walking task. First, with the degree of hearing loss exhibited by these participants, it is likely that they are not able to take advantage of the low frequency energy cues along the wall despite the "replacement" of the low frequencies in the two DSL conditions. Although the exact frequency spectrum of these cues has not been verified, it is believed to be as low as 200 Hz and below. Further, as mentioned earlier, it is possible that our population of participants does not utilize such sophisticated skills on a regular basis.

Real World Experience

In addition to experimentally-controlled test conditions, it was of interest to determine if the study participants would enjoy the ability to switch back and forth between a directional and omnidirectional microphone in their everyday lives. Recall that the hearing instrument used for this study allowed the user to switch, via a digital remote control, between directional and omnidirectional microphones. Four of the more cooperative participants were selected to take their hearing instruments home for a 1 month period and wear them as much as possible in different environments. Two programs were available to the participants, the directional DSL and the omnidirectional DSL. Each participant was called by telephone once a week by a research assistant and asked a series of questions on the usability of the device.

Two children, one 12-year-old with mild hearing loss and one 16-year-old with severe hearing loss participated in this portion of the study. Two adults also participated, one was an architect with severe hearing loss and one was a homemaker with mild-to-moderate hearing loss. Two of the participants (1 child with mild hearing loss and 1 adult with mild-to-moderate hearing loss) reported that they preferred the use of the omnidirectional microphone in all environments because the directional microphone condition was not loud enough. This report was surprising because both microphone conditions were matched in terms of frequency-shaping and gain characteristics. It is possible that when in the directional microphone mode the participants were not facing in the direction of the speaker of interest. The proper heading of the listener when using a directional microphone has been demonstrated as an important component of directional microphone benefit (Lee, Lau and Sullivan 1998; Ricketts 2000; Henry and Ricketts 2001).

Three of the participants reported that the use of the remote for changing the microphone conditions was inconvenient. It is not known whether this inconvenience was specific to these participants because of their visual deficits. One participant suggested that he would prefer to have the microphone switch on his hearing instrument as opposed to using a remote switch. Times reported when the directional microphone was preferred included when in meetings if everyone was stationary, and in very noisy environments (i.e., the gymnasium at school).

Conclusions

Much research has been conducted on hearing instrument specifications designed to enhance speech recognition ability but considerably less, if any, exists on the enhancement of environmental auditory cues. Because speech perception is highly dependent upon frequencies above 500 Hz, it is common for hearing instruments to attenuate frequencies below that level. That low frequency range, however, contains critical information for orientation and mobility with respect to traffic sounds and environmental surfaces such as walls. In addition, microphone characteristics may have different impacts on orientation and mobility skills versus speech perception skills. In this preliminary study of this topic, we found, as have numerous other investigators, that directional microphones provide an advantage when listening to speech in noise under laboratory conditions. However, omnidirectional microphones appear to enhance localization ability under certain laboratory conditions and, perhaps, in real world settings.

A considerable amount of research is still needed in order to increase our knowledge in this area. In the meantime, one should be cautious when selecting microphone options for use by individuals with significant vision and hearing deficits. It appears reasonable to offer a switchable directional/omnidirectional microphone option to those with significant visual impairments who must rely on their hearing for getting around their environments safely. Instruction regarding careful head positioning during communication especially when using a directional microphone is warranted. This instruction is likely to be reinforced for the individual with dual sensory impairment if audiologists and orientation and mobility instructors remain in close communication.

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Author Note

Anne Marie Tharpe, Dan H. Ashmead, Todd A. Ricketts, Ann M. Rothpletz, and Robert Wall, Department of Hearing and Speech Sciences, Vanderbilt Bill Wilkerson Center for Otolaryngology and Hearing and Speech Sciences. We gratefully acknowledge Phonak AG for their financial support of this project. We thank Metropolitan Nashville Hearing Impaired Program, Tennessee Technical Assistance and Resources for Enhancing Deafblind Supports (TREDS), Veteran's Administration Hospital, and Vocational Rehabilitation for assistance in participant recruitment. In addition, we appreciate our research assistants for this project, Candace Bourland Hicks, Hollea McClellan, Carisa Reyes, and Amy Warner. Finally, we thank the participants who gave their time and energy to this project.

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