Critical Review: Do School-Aged Children with Hearing Loss have Improved Speech Recognition in Noise when Using Directional Microphones versus Omni-directional Microphones?

Johnson, K.
M.Cl.Sc (Audiology) Candidate
School of Communication Sciences and Disorders, U.W.O.

This critical review examines whether school-aged children perform better on speech recognition tasks when using directional microphone hearing aid technology, as compared to conventional omni-directional technology. Overall, the reviewed literature indicates that directional microphone technology improves speech recognition in background noise for children with hearing loss. However, the research also suggests that the use of directional microphone technology to improve signal to noise ratio (SNR) should only be considered for older children and only when FM technology, the system of choice in difficult listening environments, is not being used.

Introduction

One of the primary complaints from individuals with sensorineural hearing loss is their inability to hear effectively in background noise. Studies with adults and children have revealed that even individuals with a mild sensorineural hearing loss can have significantly reduced speech perception in noise compared to individuals with normal hearing, and greater degrees of hearing loss result in a further degradation of performance (Meston, 2006).

Early childhood is a crucial time for speech and language development and any delay in this area can have adverse effects on other aspects of development. The classroom environment is where the majority of children's language, literacy, and speech development occurs. However, classroom noise levels (e.g. in kindergarten, on the playground, etc.), along with reverberation and large speaker-to-listener distance have been identified as the primary problems for children with hearing loss. Thus, it is crucial that when providing hearing instrument technology to children with sensorineural hearing loss the relevant speech signal is louder than the irrelevant background noise. Consistently achieving this positive SNR is one of the biggest challenges faced by pediatric audiologists.

Although there are a number to technologies (FM systems, Direct Audio Input, etc.) that can improve SNR, directional microphones are the only hearing aid option (Dillon, 2001). Directional microphones allow individuals with hearing loss to hear more easily in background noise by reducing the sensitivity to sounds arriving from directions behind or beside the user and favoring the pick-up of sounds arriving from the front. This is in contrast to traditional omni-directional microphone technology that picks up sound equally from all directions.

The use of directional microphone technology to improve the SNR for adult hearing aid users is well documented. However, limited research exists regarding the efficacy of directional technology for children. There are a number of important factors to consider when fitting infants and young children with directional microphone technology. For instance, when children are developing speech and language they require access to sounds from all directions since lateralization and localization are learned skills, which are critical to a child's safety. Thus, audiologists are faced with the crucial decision of whether or not to fit directional microphone technology on children. Two studies were found that investigated the efficacy of directional microphone technology versus omni-directional technology for improving children's speech recognition in noise, and both studies have been included in this critical review.

Objective

The primary objective of this review was to critically evaluate the existing literature regarding the efficacy of directional microphone technology for improving school-aged children's speech recognition in noise. The secondary objective was to propose evidence based recommendations to pediatric audiologists for use when making amplification decisions.

Method

Search Strategy

Computerized databases, including PubMed and Medline, were searched using the following search strategy: ((directional) AND (microphone$) AND (children) AND (hearing aid$). The search was limited to articles written in English. A pediatric expert was also contacted for guidance and provided relevant literature. Other articles were acquired through article referencing.

Selection Criteria

Studies selected for inclusion in this critical review were required to investigate whether directional microphones provide greater speech recognition in noise than omni-directional microphone technology when used by school-aged children. No limits were set regarding the methodological design of the research studies.

Data Collection

Research of the literature yielded the following types of articles congruent with the selection criteria: group comparison in an experimental design using a three-way mixed statistical analysis of variance (2).

Results

Gravel, Fausel, Liskow, and Chabot (1999) examined the efficacy of dual-microphone technology versus omni-directional microphone technology by assessing children's speech recognition abilities for words and sentences presented in multi-talker background noise. An adaptive test procedure was used to estimate the SNR that reduced the children's speech recognition abilities to 50% in noise. A secondary goal of the study was to determine if children's receptive language ability was correlated with the outcomes. The children's receptive language ability was assessed using the Receptive One Word Picture Vocabulary Test (Gardner, 1990). Based on the raw test score, each child was assigned a language age.

Participants were 20 children with bilateral cochlear hearing loss and normal middle ear function, ranging in age from 4 to 11 years (ten children aged 4-6 years, ten children 7-11 years). There was no significant difference in degree of hearing loss between the two age groups. The children were all recruited from the Children's Hearing Intervention Program in Bronx, New York. All of the children were regular users of binaural Behind The Ear (BTE) hearing aids and were fitted for the study with bilateral Phonak PiCS programmable hearing instruments using the Desired Sensation Level (DSL) program version 3.1.

The collected data were analyzed using a three-way mixed design analysis of variance. Significant effects were found for microphone type, speech material, and age group. A post hoc comparison was completed using the Tukey honestly significant difference method. Significant differences were found between the mean SNRs obtained from the younger children versus the older children in both the dual-microphone and omni-directional conditions for both words and sentences. Specifically, the older children tolerated approximately 4-6 dB more background competition than the younger children when listening to words and sentences in either microphone condition. To further examine the relationship between receptive language age and outcome, an analysis of covariance with language age as the covariant was performed. Significant effects were found for microphone type and speech material, but not for age group. Finally, correlations were completed to examine associations between outcomes, chronological age, language age, and degree of hearing loss. Receptive language ability was highly correlated with the outcomes, as well as chronological age.

Thus, in summary, it was found that under the test conditions used, the dual-microphone condition provided a significant advantage over the omni-directional microphone condition for listening to words and sentences in background noise for both age groups. However, the younger children required a higher SNR than the older children in order to perform at the same level.

Kuk, Kollofski, Brown, Melum, and Rosenthal (1999) evaluated the efficacy of directional hearing aids with low compression thresholds in a school-aged population. Specifically, they examined the percentage change in speech recognition scores, using the CID W-22 word lists, offered by the study hearing aids over the patient's own hearing aids in varying degrees of background noise. Levels of 72, 65, and 52 dB SPL were presented in the presence of 65 dB SLP party noise. The researchers also evaluated the subjective real-world benefit offered by the study hearing aids in the school and in the child's daily environment using the Listening Inventory for Education (LIFE) questionnaire and a parent questionnaire.

Participants were 20 children aged 7 to 14 years recruited from 18 different elementary schools. The children were separated into two groups based on their degree of hearing loss; mild to moderately severe and moderate-to-severely-profound. All of the children were previous users of bilateral analog hearing aids. For the purpose of the study all of the children were fitted with Widex Senso digital hearing aids, and were given 30 days to acclimatize to the aids prior to the initial testing.

Speech recognition scores were analyzed using a three-way mixed analysis of variance (F-stat) with microphone type and SNR as within subjects variables and severity of hearing loss as a between subjects variable. Significant main effects were found for all three variables. Post hoc analysis was performed using the Honestly Significant Difference Test. Results indicated that the mean scores for the digital directional hearing aids were significantly higher than the mean scores for the children's own

omni-directional analog hearing aids at each of the three SNR levels assessed. On the LIFE questionnaire the digital directional hearing aids were rated higher by the students than their own omni-directional analog hearing aids (some with FM) in many of the listening situations listed. Of the parents who completed the parent questionnaire, 16 of 18 reported that the digital directional hearing aids improved their child's listening.

The results of this study revealed that children's speech recognition performance was improved when using directional technology in a typical laboratory environment. Ratings of school behavior on the LIFE questionnaire were higher when using the digital directional hearing aids, and there was a preference for keeping the digital directional aids over the children's own omni-directional analog hearing aids.

Discussion

Both of the reviewed studies assessed the effectiveness of directional microphone technology over traditional omni-directional microphone technology in a population of school-aged children. The results of both studies revealed that directional microphones provide a significant advantage over omni-directional microphones for speech recognition in noise by children with sensorineural hearing loss up to a severe degree. However, there were a number of limitations to the findings. First, both studies used small sample sizes of twenty children and testing was conducted in a typical laboratory environment (e.g. low reverberation and fixed azimuths of signal and competition) using closed sets of monosyllabic words and sentence materials. The results obtained under these conditions may not reflect children's performance in a real world listening environment where there is significant reverberation and speech messages are unrestricted. Second, during the speech in noise testing of both studies a single noise source was presented from 180 degrees azimuth to the children. This presentation provides limited external validity, because noise typically comes from all directions in children's daily listening environments. Directional microphone studies that have been conducted with adults have presented noise at five azimuths to the sides and back of the listeners (Ricketts & Dhar, 1999). This type of presentation would have improved the external validity of the reviewed studies. Finally, because the study by Kuk et al. (1999) compared digital directional hearing aids to analog omni-directional hearing aids, it is difficult to say if the children's improved performance and preference for the digital directional hearing aids can be attributed to the directional microphone technology alone rather than a synergistic effect of all the digital hearing aid features. Kuk et al. (1999) attempted to increase the external validity of their study by using subjective measures of performance and found that the advantages of a directional microphone can be seen in an improvement of listening behavior in the classroom and at home.

Despite the demonstrated advantages of directional microphones in the reviewed studies, both caution the application of these findings when fitting infants and young children for a number of reasons. First, directional microphones create a reduction of sounds arriving from directions other than in front of the listener and infants and young children require these inputs in order to develop basic auditory processes, such as selective listening and localization. Second, children require acoustic inputs from all directions in order to attend to important communication messages and environmental sounds for the purpose of safety. Finally, the use of directional microphone technology by children may have an adverse effect on the incidental learning of speech and language in the child's daily environment.

In summary, outcomes from the studies demonstrate that school-aged children with varying degrees of hearing loss have improved speech recognition in background noise when using directional microphone technology as compared to omni-directional microphone technology. However, these research findings are limited to controlled laboratory testing environments. Due to the limited amount of research that has been conducted in this area, the question of benefit and use of directional microphone technology in the pediatric population remains inconclusive.

Recommendations

At present, audiologists should employ caution when deciding whether or not to fit a child with directional microphone technology. Despite the fact that directional microphones have been shown to improve children's speech recognition in noise, there remain a number of speculations surrounding the use of this technology for reasons related to safety and speech and language development.

Based on the reviewed literature, it appears that at this time directional microphone technology should only be considered for older children and only when FM technology, the current system of choice to improve SNR, is not being used. Older children may reject the use of FM technology when cosmetics or portability become a significant concern and this would be an appropriate time to consider the use of a directional microphone. That said, when directional microphones are prescribed for children the option

should be variable. In other words, the selected hearing aid should provide the wearer with the ability to switch between directional and omni-directional conditions. However, use is cautioned with younger children because research indicates that the use of multi-program functions is highly age dependent (Bohnert & Brantzen, 2004). For instance, young children may switch into a directional program when in a noisy environment, but then forget to switch back when in quiet. Due to advanced digital technology it is possible for audiologists to de-activate the directional program until the child is old enough that they are capable of adjusting their program settings appropriately and reliably based on different listening situations in order to optimize communication.

It is important for audiologists to counsel caregivers about which listening situations could be improved with the use of a directional program, so that parents can assist the audiologist in deciding when this technology would be appropriate for their individual child based on personal and environmental factors. If caregivers are motivated to manually switch between directional and omni-directional programs, using a program switch or remote control, depending on their child's particular listening environment, than that child may be able to make use of directional technology at a younger age. However, whether parents can truly master appropriate and reliable switching between two or more hearing aid programs remains to be demonstrated through field trials. Thus, the decision regarding when to set up a directional program for a child should be at the discretion of the clinician.

Further research is required in order to more clearly understand the appropriateness of providing directional microphone technology to the pediatric population. Classroom noise levels, reverberation, and large speaker-to-listener distances are primary communication barriers for children with hearing loss and therefore, studies of directional microphone technology need to be conducted in real-world listening environments. These future studies should use larger sample sizes, minimize confounds, and include follow-up testing. Further, these studies should focus on the effects of directional microphone technology on safety, incidental speech and language learning, and development, so that clinicians are provided with more clarity regarding these concerns.

References

Bohnert, A., & Brantzen, P. (2004). Fitting with a digital directional hearing aid. Retrieved December 2, 2007 from http://www.thehearingreview.com/issues/articles/2004-02_06.asp

Dillon, H. Hearing Aids. Boomerang Press, Sydney, 2001.

Gravel, J., Fausal, N., Liskow, C., & Chobot, J. (1999). Children's speech recognition in noise using omnidirectional and dual-microphone hearing aid technology. Ear and Hearing, 20 (1), 1-11.

Jones, C. (January 13, 2005). Fitting Young Children with Directional Technology. Retrieved January 12, 2007, from http://www.audiologyonline.com/askexpert/display_question_id=150.

Kuk, F., Kollofski, C., Brown, S., Melim., & Rosenthal, A. (1999). Use of digital directional hearing aid with directional microphones in school-aged children. Journal of the American Academy of Audiology, 10 (10): 535-548.

Meston, C.N. (2006). Acceptable noise levels and speech perception in noise for individuals with normal and impaired hearing. Thesis Monograph. The University of Western Ontario, London, Ontario.

Ricketts, T., & Tharpe, A.M. (2004). Chapter Ten: Potential for Directivity-Based Benefit in Actual Classroom Environments. *A Sound Foundation Through Early Amplification 2004.* Edited by R. Seewald & J. Bamford, 143-153.