

Critical Review:
Do Directional Microphones Provide Benefit For Young and School-Aged Children Compared to Omnidirectional Microphones?

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The purpose of this review is to look at the potential benefit of directional microphones for young and school-aged children. This review looked at several studies with varying factors that determined benefits including speech recognition, surveys, and video recordings. Based on the current research directional microphones have been shown to provide a degree of benefit in certain situations, mainly with the speaker in front of the listener, while detrimental in others, with the speaker behind the listener. Based on these observations, there is not enough evidence to support the routine use of directional microphones with young and school-aged children.

Introduction

Using directional microphones in adults is a common clinical practice. The efficacy of this type of microphone for adults has been heavily researched. However, using directional microphones in pediatric hearing aids has not. The position of the American Academy of Audiology (2004) is that younger children should not be given a directional microphone until they are older and can learn to switch between a directional and omnidirectional microphone. Their position is based on the notion that children learn from the world around them, not just in front of them. This position is in stark contrast to the position of the King (2009) article describing the national protocol for pediatric amplification in Australia. The King protocol is to provide all children with directional microphones, a position which is based on the work of Ching et al (2009), which will be discussed further. These two contrasting views illustrate the importance of understanding whether directional microphones are appropriate for children, from infancy to early adolescence.

Objectives

The primary objective of this review is to evaluate the literature concerning directional microphone benefit for young and school aged children. A secondary objective is to explore the protocol mandated in the United States of America and Australia for determining the utilization of directional microphone arrays in hearing aids provided to children.

Methods

Search Strategy

Several computerized databases were utilized in order to locate articles. These included: PubMed,

Medline-OVID, CINHL, and SCOPUS. These databases were searched using the following strategy where permitted:

(directional microphone) OR (directional microphone hearing aid) AND (child) OR (children) OR (pediatric). Additional papers were located with the guidance of Dr. Susan Scollie.

Selection Criteria

Papers were selected based on their relevance to the topic. Those dealing with the use of directional microphones with patients for reasons other than to deal with hearing loss (e.g. for the treatment of auditory processing disorder) were also excluded. Only papers that were accessible via internet, the University of Western Ontario library system, or RACER were used in this review.

Data Collection

Four papers will be discussed in this review and includes three studies; 2 within-groups repeated measures and 2 mixed, both within and between group measures.

Results

The purpose of the Ricketts & Galster (2007) study was to examine a child's performance in several simulated classroom environments for both an omnidirectional and directional hearing aid. The authors used a within groups (repeated measures) experimental design over 3 sub-experiments to determine performance.

The first experiment modeled five classroom conditions (teacher front, teacher back, discussion, desk work, and bench sitting), and using the HINT-C determined the performance of hearing aids that were set to omnidirectional and directional modes. Two surveys, the Children's Home Inventory for Listening Difficulties (CHILD) and a questionnaire that was

designed specifically for this study, were used to assess the situations in which the directional microphone could be judged either positively or negatively. Post hoc analysis showed that participants performed better with directional microphones in the teacher front ($p < .0436$), desk work ($p < .0001$) and discussion ($p < .0001$) classroom conditions. There was no difference between the two settings for bench work. Using the Bonferroni correction, no significant subjective performance between the omnidirectional and directional microphones was found using the CHILD survey.

The second experiment was designed to obtain additional data regarding the effects of omnidirectional and directional modes for when the speaker of interest is either in front or behind the listener. It was also designed to include a condition in which the low frequency processing in the directional mode was reduced in order to determine if this would mitigate some of the negative effects associated with directional microphones. Children were presented with nonsense syllables from the City University of New York, Nonsense Syllable Test (CUNY-NST) in both teacher in front and teacher in back conditions, with the three degrees of directionality. Percent-correct performance values were first arcsine transformed to data analysis (to normalize the variance) and were then analyzed using a two-factor ANOVA. The Tukey honestly significant difference test revealed a significant main effect of microphone mode and source location, as well as a significant interaction between microphone mode and source location. Post hoc analysis revealed that while participants performed better in directional mode when the speaker was in front there was no difference between the omnidirectional and low-pass filtered condition. When the speaker was in the back the omnidirectional mode showed an advantage over the other two microphone modes ($p < .0001$).

The third experiment looked at the affect of directional vs. omnidirectional microphone modes when the competing noise is the same loudness as the speaker. 12 participants were used from the previous two studies. Word recognition was measured using the Northwestern University Auditory Test No. 6 and presented with competing cafeteria noise that was spectrally matched to that of the NU-6 noise. The participants were presented with a NU-6 list presented from either the front, right back or left back. Percentage-correct performances were arcsine transformed in order to normally distribute them. The results were analyzed using a two-factor ANOVA with within-subject factors of the two microphone modes and the three source positions. There were significant effects of both the microphone mode and source location and a significant interaction between the two. Post hoc analysis revealed that in the front speaker condition there was no difference for microphone mode but when the speaker of interest was

back right or back left, there was an advantage for the omnidirectional mode, $p < .0036$ and $p < .0078$ respectively.

Based on the above three experiments the authors maintain that unless the talkers are in front of the children omnidirectional microphones should be used with children.

Gravel et al (1999) were interested in determining whether the use of a hearing aid with a directional microphone array would increase speech recognition in noise as compared to an omnidirectional microphone array. A secondary goal was to test if the type of speech material, child's chronological age, receptive language abilities and amount of hearing loss had an effect on the outcome. The authors used a within and between group measures research design to determine the outcome.

Twenty children ranging in age from 4 to 11 years were used who had a diagnosed bilateral cochlear loss; the degree of loss ranged from mild to severe. The children were also separated into two groups based on age, those who were of preschool age and school age. The children were presented speech stimuli from the Pediatric Speech Intelligibility (PSI) test and were divided into words and sentences. These were presented to the children from the front while competing multi-talker babble was presented from behind. Each child heard both types of samples of the PSI in both omnidirectional and directional mode over several sessions. All four conditions were counterbalanced.

The data was analyzed using a 3-way mixed design analysis of variance with two within-subject factors, microphone and speech materials, and one between-subject factor, age. The authors noted an affect of age and type of microphone; with the directional microphone providing a mean of 4.7 dB, on the outcomes and significant individual variance in benefit. The authors concluded that directional microphones may provide benefit and may be considered by pediatric audiologists as an option but would work best if the user, or their parents/teacher, were able to switch between an omnidirectional and directional microphone array depending on the situation.

The study was valid in design, however limited in generalizability. This is due to the study being conducted in a laboratory setting which the authors noted may not be representative of the actual environment.

Kuk et al (1999) compared digital directional hearing aids and omnidirectional hearing aids in school-aged children in both laboratory and real-world settings. A secondary purpose was to determine whether age had any impact on the benefit. A within and between group measure experimental design was used.

Twenty children ranging in age from 7 years 6 months to 13 years 9 months who have been previously diagnosed with sensory neural hearing loss were used for this study.

Participants were presented with a recorded W-22 world list with competing Widex party noise presented at 65 dB SPL and were asked to compare their own omnidirectional hearing aids with the directional hearing aids provided for this study (Widex Senso C9/C19 depending on the degree of hearing loss), with 30 days for acclimatization in between. The participants, along with their parents and teachers, were also asked to complete the Listening Inventory for Education (LIFE).

The results for the speech recognition scores were analyzed using a 3-way mixed analysis of variance with two within-subject factors (microphone type by SNR) and one between-subject factor (severity of hearing loss). There were significant main effects for all three factors; microphone ($F=9.3$, $p=.003$), SNR ($F=18$, $p=.000$) and severity of hearing loss ($F=19.8$, $p=.000$). There were lower speech scores for those participants who wore the C19 hearing aids, which may be due to the degree of hearing loss.

The LIFE survey results indicated that participants rated the study hearing aids more favorably in all but one condition (teacher moving) where there was no difference between the aids. The teacher portion of the survey, which was only filled out by 10 of the 20 participants' teachers, indicated that only one teacher believed the participant to be highly successful with their new hearing aids, 4 as successful, 2 as minimally successful and 1 as seeing no difference in the child.

Based on these results the authors conclude that hearing-impaired children, up to a severe hearing loss, would benefit from the advantages that directional microphones give.

Limitations of the study include that the baseline for the study was using the participants' own hearing aids, thus confounding factors other than simply omnidirectional vs. directional may be present. Also, only half of the teachers contacted responded with this not being accounted for.

Ching et al (2009) were interested in examining the effects of directionality on infants and young children in naturalistic settings to determine the implications for the use of directional microphones in this population. The authors used a qualitative research design along with survey research to determine whether children turned toward a speaker on their own. The authors utilized a within-groups repeated measures to conduct their study.

A total of 27 children were used in this study ranging in age from 11 months to 5 years with 16 of them having a hearing impairment. Video recordings of the children

were made in four naturalistic settings chosen by the parents and were used to determine whether a child turned their head towards a speaker. The parents were also asked to keep a diary of their child's perceived behaviour while being recorded.

The video recordings were visually analyzed to determine whether the child turned their head towards a primary speaker; instances during which the child was speaking to themselves or a conversation involving several speakers not directed towards the child were excluded. The diary entries were divided up into several categories based on whether they were related to indoor or outdoor and whether they were related to a single or multiple situations.

Statistical analysis using ANOVA revealed that there was no significant effect of age or hearing ability in the results. Analysis indicated that 40% of the time children oriented their head toward the speaker with no age or hearing status effect. Electroacoustic analysis of hearing aid performance indicated that the overall advantage of directional hearing aids was -0.4 dB to 0.2 dB across situations. The authors suggest that this shows children may benefit from directionality for certain listening situations, especially if hearing aids were able to switch reliably between omnidirectional and directional.

There are several limitations to this study. Although the title of this study suggests that these principles apply to infants, only one child under the age of 1 was used. This study also heavily discusses and promotes the use of directional microphones in the hearing aids of all children, yet not one child in this study wore a directional hearing aid. Another limitation of the study involved the exclusion of video data in which there was a conversation not directed towards a child. There is strong literature regarding the importance of overhearing conversations to a child's learning a language (Akhtar et al 2001, Akhtar 2005). The exclusion of this data from the study represents a limit on its validity.

Discussion

Each of the four studies whose results are summarized make claim that there are certain situations in which directional microphones provide children with a certain degree of benefit in certain situations. All the studies used proper scientific methods; with the Ricketts & Galster (2007) and Ching et al (2009) studies each at a 2b level of evidence and the Gravel et al (1999) and Kuk et al (1999) studies at a level of 2a. However, there are many weaknesses that can be seen in the interpretation of results. The Kuk et al (1999) study appeared to actually be determining whether the Widex Senso was a superior hearing aid to the participants'

older models and conclusions concerning which microphone type is better may be secondary. The Gravel et al study (1999) was more honest with its limitations than other studies, but still made conclusions regarding the potential benefit of directional microphones in children. The study with perhaps the least generalizable findings are found in Ching et al. (2009) in which no children wore directional microphone hearing aids yet the authors recommend directional usage based on their results. Ricketts & Galster (2007) offered the most rigorous of the studies presented and provide data on performance in real world environments with directional microphones with school-aged children. These authors caution against the use of full time directional modes.

Clinical Implications

Pediatric hearing aid fitting is already a challenge due to the physical characteristics of children's ears, among other factors. When selecting a hearing aid for infants, young children, and school-aged children there are certain guidelines one should follow. In Ontario the College of Audiologists and Speech-Language Pathologists of Ontario has preferred practice guidelines for hearing aid fittings in children. Yet within the document there is no guidance with regards to advanced features such as directionality. Thus, the clinician must look elsewhere, like the ASHA guidelines or the Australian protocol, two documents that have an opposing stance on the issue. This can make it difficult for the clinician to make a choice. However, looking at the evidence presented, with the Ricketts & Galster study being the most rigorous, a conservative approach to directional microphones with children is at this time recommended. This mirrors the guidelines presented by ASHA.

Recommendations

Given the current research, there is not enough evidence to suggest that directional microphone hearing aids provide adequate benefit to mandate their routine use with children. Most of the studies discuss postulate that if the child could switch between the omnidirectional and directional microphones there are situations in which the directional microphone would be beneficial. Additional research into what age a child could be taught to correctly switch between the two modes would be of benefit. Future research should also be more stringent with specific age ranges. Children do not develop on a yearly basis but a month-to-month one and all future research should take this into advisement. There should also be research done to determine if there is a risk of harm to children with regards to using

directional microphones and them not hearing warning signals behind them.

Conclusion

As can be seen the use of directional microphones in children is an area of much contention. The American Academy of Audiology and the Australian national protocol have opposing views on the subject. Based on current research, there is not enough evidence to support the routine use of directional microphones in very young and school-aged children. Providing children with directional microphones at an early age can potentially put the child at danger if they cannot hear warning signals behind them. Children may also be at risk of missing out on language-learning opportunities.

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