Critical Review: Is There a Benefit for School-Aged Children with Hearing Loss to Use Directional Microphones in the Classroom to Improve their Speech Recognition Performance?

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This critical review examines whether school-aged children with hearing loss improve their performance on speech recognition tasks in a classroom environment when using directional microphones, as compared to customary omni-directional microphones. A review of the literature indicates that children experience a significant directional benefit when the sound source of interest is in front of them, but a directional deficit when the sound source of interest is behind them. However, the research also suggests that child's ability to orient their heads to a sound of interest is dependent on their focus on the task at hand.

Introduction

Poor signal-to-noise ratios (SNRs), not unlike those found in classroom environments, can significantly reduce the speech understanding in both children with and without hearing loss (Ricketts, et al., 2007). There is also considerable evidence to suggest that children with hearing loss require improved SNRs for the same speech recognition performance as compared to listeners with normal hearing (Ricketts, et al., 2007). Without an improvement in SNR, children with hearing loss will miss out on a lot of classroom conversation. Both formal and informal interactions with their teachers and peers are necessary to optimize education and learning. To date, microphone technology has been used with great success in improving the SNR in noisy environments such as classrooms.

The most effective and widely used technology to date to improve speech understanding in noise is the frequency modulated (FM) system. Little doubt exists that this intervention is preferred in classroom settings when only the teacher's voice is of interest (Ricketts, et al., 2007). A discrepancy arises when one considers situations in which there is more than one speaker of interest. Informal school settings such as buses, lunchrooms and playgrounds can all be formative in a child's social, cognitive and linguistic development (Ricketts, et al., 2007). For this reason, improving the SNR should not be limited to formal instructional settings but to all noisy situations where communication is subsequently limited (Ricketts, et al., 2007).

Directional microphone technologies have been shown to improve speech recognition in noisy environment by adult listeners when used in comparison to the conventional omni-directional microphone (Ricketts, et al., 2007). Likewise, in children, directional microphones have been advocated for use in environments where there are multiple sound sources of interest (Ricketts, et al., 2007).

Factors known to affect the directional benefit in adults include the magnitude of the room's reverberation, speaker-to-listener distance, and the position of the sound sources of interest relative to the listener (Ricketts, et al., 2007). Investigating the effects of these factors in children is critical to determining a directional benefit or decrement to the child and their language development and understanding. Dispensing audiologists are currently faced with the decision to fit directional microphones on school-aged children or not, based on existing evidence. Two studies were found and are included in this critical review to evaluate whether or not there exists enough evidence to fit directional microphone technology, for improving speech recognition, in school-aged children in the classroom.

Objectives

The main objective of this critical review was to examine the efficacy of directional microphones in improving the speech recognition performance in school-aged children through a review of the existing literature. In addition, to provide evidence-based recommendations to dispensing pediatric audiologists so that they can make the most appropriate decisions in amplification fittings for their patients.

Methods

Search Strategy

Computerized databases, including PubMed and Medline were searched with the following strategy: ((directional) AND (microphone$) AND (classroom)) and ((classroom$) AND (amplification)). The search was limited to articles written in the last five years and to articles written in English.

Selection Criteria

Studies selected for this critical review were required to evaluate the performance of directional microphones versus omni-directional microphones in speech recognition tasks in the classroom of school-aged children. Additionally, those studies that investigated directional benefit and their potential in the classroom environment were also considered. No limits were set regarding the methodological design of these studies.

Data Collection

A review of the literature yielded the following types of articles that were consistent with the selection criteria: a within groups (repeated measures) with counterbalancing experimental design and a case control study (quasi-matched control groups).

Results

Ricketts, Galster, and Tharpe (2007) examined the objective and subjective performances of children in directional microphone mode and omni-directional microphone mode over a series of three experiments in a range of simulated classroom environments. Speech recognition performance of each participant was measured using the Hearing In Noise Test – Children (HINT-C), City University of New York Nonsense Syllable Test (CUNY-NST), and the Northwestern University Auditory Test No. 6 (NU-6) in experiments one, two, and three, respectively (Ricketts, et al., 2007). Two questionnaires were used to evaluate subjective performance of each microphone setting in experiment one. Each participant and their parent completed the Children's Home Inventory for Listening Difficulty (CHILD) along with a 16-question questionnaire developed by the authors specifically for this study, which noted the participants strengths and weaknesses in each microphone mode in different listening environments (Ricketts, et al., 2007). In experiment one, participants were counterbalanced and assigned to a microphone mode that they would wear for one month. After one month, they were evaluated objectively and subjectively based on only the microphone mode they had used the previous month. The second month participants would switch modes and repeat evaluation at the end of the month.

Participants were 26 children aged 10-17 years all with hearing loss. Twenty-four of the children had prior experience with bilateral amplification, however none had experience with directional hearing aids. The average ear-specific air-conduction thresholds across participants were approximately 55 dB HL. All participants were fitted with bilateral, behind-the-ear hearing aids capable of directional and omni-directional modes using the Desired Sensation Level (DSL) fitting method v. 4.1 (Ricketts, et al., 2007). Twenty participants were fitted with Oticon Gaia's while the remaining six were fitted with the Phonak Supero based on their broader fitting range.

The collected data in experiment one were analyzed using a two-factor analysis of variance. Significant effects were found for microphone type and test environment. Tukey's honestly significant difference was used in post hoc analyses of the data. Participant performance was shown to be significantly better in directional mode in the Teacher Front, Desk Work, and Discussion conditions (Ricketts, et al., 2007). On the other hand, participant performance was significantly worse in the directional mode in the Teacher Back condition (Ricketts, et al., 2007). Individual *t* tests were conducted for each item on the CHILD and developed questionnaire, however no significant differences between directional and omni-directional modes were noted.

To further examine the effects of speech perception in each microphone mode experiments two and three were analyzed using a two-factor analysis of variance. For post hoc analysis, Tukey's honestly significant difference test was again used and significant effects included microphone mode, source location and an interaction between microphone mode and source location. Analysis revealed that when the source was in front of the listener performance was significantly better in the directional mode and when the source was behind the participant, performance was significantly better in the omni-directional mode (Ricketts, et al., 2007).

Thus, in summary, it was found in the test conditions used that a significant directional benefit was observed when the sound source of interest was in front of the participant with noise surrounding them. Also, a directional decrement was measured when the sound source of interest was behind the participants. In this condition, omni-directional mode yielded a higher performance.

Ricketts and Galster (2008) set out to quantify the angle and elevation of children's heads relative to sound sources of interest in actual classroom environments. One of the goals of this study was to gather the data and determine the potential for directional benefit in terms of candidacy and appropriateness in school environments all based on whether or not children could accurately orient their heads toward sound (Ricketts & Galster, 2008). This ability to orient to sound is critical for directional users. Children who lack this ability would be faced with a microphone mode that would be

detrimental. The authors also wanted to determine if head orientation was dependent on age or hearing status.

Participants were forty children aged 4-17 years separated into two groups, an older group and a younger group to determine if age affected accuracy. Half of the participants had normal hearing while the other half had hearing loss, to evaluate whether hearing status affects accuracy. The groups were matched to obtain as many classroom pairs as possible (two children of same gender, same classroom, one with hearing loss, one with normal hearing).

Data were gathered through use of three video cameras placed in the classroom at various positions that could measure head angle and elevation and position of sound sources relative to participant. Recording sessions were identified in cooperation with classroom teacher and thus it is unclear how representative taped sessions are of an entire school day. It was clear that majority of sessions included a high percentage of teacher speaking time indicating a didactic classroom environment.

The collected data were analyzed using analysis of variance techniques. A significant main effect of deviation plane was determined, which revealed greater deviations in the vertical plane than the horizontal plane (Ricketts & Galster, 2008). Tukey's honestly significant difference was used in post hoc analyses of the data. Participant performance indicated no significant differences across groups within the horizontal plane. However, in the vertical plane, the older participants displayed a significantly larger average deviation than the younger participants (Ricketts & Galster, 2008). Further analysis of variation was considered on the percentage of time that participants turned toward brief utterances. There was a significant main effect of hearing status. Participants with hearing loss turned towards brief utterances significantly more often than those participants with normal hearing (Ricketts & Galster, 2008).

In summary, it was hypothesized that in real classroom environments head angle accuracy was dependent on listening task. Children are able to orient their head accurately toward sound but because of task demands they are not always willing to do so (Ricketts & Galster, 2008). As well, children with hearing loss are more likely to attend to brief utterances than were children with normal hearing. This is suggested because children with hearing loss have an increased need for visual information to enhance speech perception (Ricketts & Galster, 2008).

Discussion

In the first study, Ricketts, Galster and Tharpe (2007) evaluated the effectiveness of directional microphone technology compared to omni-directional microphone technology in a variety of different listening conditions. The results of this study support the use of omni-directional microphone mode for school-aged children in classroom environments where multiple talkers and conversations are of interest (Ricketts, et al. 2007). However, if all speakers are located in the front hemisphere, in relation to the listener, directional microphones are encouraged so that a directional benefit can be achieved (Ricketts, et al. 2007). The authors did find significant directional benefit in certain conditions, however it is important to consider that the classrooms were simulated and contained no other 'real-life' distracters (other children, open window, toys, etc). One must consider this setting when examining and understanding the child's ability to focus and that it will not always translate to real classroom environments.

In the second study, Ricketts and Galster (2008) examined the potential for directional benefit in real classroom environments through measurement of head angle and elevation relative to sound sources of interest. They concluded that there was no difference between older or younger children or those with hearing loss versus those without, in terms of their ability to accurately orient their head to classroom sounds of interest. While children are able to turn their head towards sounds, the authors noted inconsistency with the child's willingness at times, which was attributed to their level of focus based on the current task at hand. A major consideration when evaluating this study was the fact that multiple video cameras occupied the classroom, which could have had an effect on the child's behavior. Also, because each recording session was pre-negotiated with the teacher the footage received is not indicative of an average school day.

To conclude, the research indicated an increase in performance during speech recognition tasks in directional mode, although only when the sound source was in front of the listener. Children are also able to accurately orient their heads toward sound, but it is dependent on their level of focus and their interest to the sound and the task at hand. Furthermore, while a clear directional benefit has been shown to exist, it is situation dependent and thus not appropriate to provide ample benefit at all times and in all places. Further research efforts should be geared towards evaluating older children's abilities to manually switch between a directional and omni-directional microphone program, given the necessary training. As for younger children, working to refine the capabilities of manual switching

between programs in hearing aids with these two microphones as well as their effectiveness in real world settings would be advantageous.

Recommendations

At this time audiologists should exercise caution in prescribing directional hearing aids for children. Directional microphone technology has been shown to be advantageous in some settings however it is not appropriate in all environments. Currently, FM systems remain to be the most beneficial technology for children in school environments. The performance and benefit of an FM system is not dependent on head angle or elevation or on the position of the speaker of interest. Directional microphone technology should be reserved for those older children who are capable of switching programs and have a concrete knowledge of when to do so based on their present listening conditions.

References

Ricketts, T.A., & Galster, J. (2008). Head angle and elevation in classroom environments: Implications for amplification. *Journal of Speech, Language, and Hearing Research. 51*. 516-525.

Ricketts, T., Galster, J., & Tharpe, A.M. (2007). Directional benefit in simulated classroom environments. *American Journal of Audiology. 16.* 130-144.