Critical Review: What are the Speech Perception Benefits of Wearing an FM System with Personal Hearing Aids Versus Hearing Aids Alone in a Classroom Environment?

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This critical review examines the speech perception benefits obtained via an FM system and personal hearing aids for middle school age children with varying degrees of hearing loss in a classroom environment. Overall, the limited available research supports the use of FM systems for all hearing impaired children in the classroom setting. More research is needed however to assess the effectiveness of newer, advanced, digital hearing aids and FM systems to evaluate whether FM systems still provide the same speech perception benefits over hearing aids alone.

Introduction

A classroom setting can often be a difficult place to learn even for a normal hearing child. The acoustical environment in the classroom can be less than optimal and can have a reverberation time that is greater then the recommended 0.4 to 0.6 seconds (Hawkins, 1984). Reverberation has been described as having an effect of smearing or distorting the speech signal. Along with reverberation, background noise levels in a classroom can be as high, if not higher, than the speech signal. It has also been shown that there is a synergistic effect of background noise and reverberation that increases the degradation of speech perception more then if a simple additive effect were present (Anderson & Goldstein, 2004). Therefore, in a classroom environment where even normal hearing children will have difficulty, children with hearing loss have to contend with the poor listening conditions, the limitations of their hearing aids in this environment, and their own degree of hearing loss. Poor listening conditions increases the effort it takes to learn and reduces the energy available for performing other cognitive functions (Flexer, 1995).

Children with hearing loss perceive speech in a fragmented manner as a result of the acoustic filter effect that occurs when hearing aids do not amplify the complete speech signal into their listening range. Although hearing aids will provide some benefit in a classroom setting in terms of raising the level of the speech signal, analog hearing aids will also amplify some of the background noise as well (Anderson and Goldstein, 2004). Along with the potential for poor listening conditions in the classroom, the further a hearing impaired child is from the sound source, the greater the speech signal will be degraded and this will negatively impact speech perception.

Fortunately, the long standing recognition of the degradation of the speech signal within classrooms has resulted in the widespread use of educational amplification technology including personal FM systems (Anderson and Goldstein, 2004). FM systems help increase the signal to noise ratio by having the teacher wear a microphone unit that sends out an amplified signal directly to the receiver unit that is connected to the child's hearing aid.

To date, there has been limited research available to indicate whether or not the addition of personal FM systems with hearing aids, as opposed to personal hearing aids alone, actually increases the speech perception benefits for a child in the classroom environment. FM systems are very expensive, but they do offer simple solutions to problems caused by listener distance and background noise (Boothroyd and Inglehart, 1998). This critical review aims to summarize and critically review the existing literature on the speech perception benefits of the FM system and hearing aids in the classroom environment, and to assess whether or not there is evidence to suggest that use of this technology should have wide-scale implementation, regardless of the costs, when fitting the middle school aged population.

Objectives

The objective of this review is to quantify and critically evaluate the available research on the speech perception benefits of FM systems and hearing aid amplification versus hearing aids alone for children in a typical classroom environment with varying degrees of hearing loss who use behind the ear hearing aids (BTE's).

Methods

Search Strategy

Computerized databases including ComDis Dome, Proquest Education, PubMed, CINAHL, Medline, AudiologyOnline.com and Google Scholar, were searched using the following search parameters:

(Hearing impaired children) and (classrooms) and (FM systems)

(FM system benefits) and (hearing impaired children)

(FM system benefits) and the (classroom environment)

Limits applied to the search were:

All articles were written in English and included middle school age children.

Selection Criteria

The papers selected for inclusion in this critical review were required to include middle school aged children with varying degrees of hearing loss wearing BTE hearing aids. In addition, one paper was selected, that met above criteria, from each decade (1980's/1990's/2000's) to see if changes in technology affected the outcomes. Each study uses a different outcome measure, or several measures, to assess speech perception benefits.

Data Collection

Results of the literature search yielded 3 articles that are congruent with the selection criteria; all used a single subject within group design with each participant serving as their own control.

Results

Hawkins (1984) looked at the speech recognition abilities in noise for 9 middle school aged children who had mild to moderate degrees of sensorineural hearing loss. This was achieved by objectively measuring the signal to noise ratio yielding a 50 percent identification of spondee words. As well, word recognition scores were obtained for three amplification arrangements at two different signal to noise ratio's (+6 and +15 dB respectively) which in previous literature has been used to represent noise levels in quiet and noisy classrooms. Each child was measured initially with new Phonic Ear BTE's and then each child served as their own control by being measured using the same procedure with the addition of a Phonic Ear FM system. Therefore, any improvement in speech perception would be based solely on the FM system because all other experimental factors were the same. No mention was made as to whether the child had an opportunity to become accustomed to the new hearing aids before they were tested.

The purpose of this well designed controlled study was to measure 9 children in a typical classroom environment for real world results. Both speech perception measure procedures were performed in a 7m x 9m x 2m classroom which was indicative of a classroom where the recruited children currently had classes; the reverberation time was measured at 0.6 seconds and found to be within normal limits for a class that size (Hawkins, 1984). The speech signals were all delivered from a loudspeaker 2 m from the child at a 0 degree azimuth; this distance was indicative of a preferred seating position for a hearing impaired child in the classroom (Hawkins, 1984). The other loudspeakers in the classroom were used to deliver background noise and were situated 4 m from the child at 180 degree azimuth. The FM transmitter microphone was located 6 inches from the speech loudspeaker to mimic a lapel worn microphone. There were 11 conditions in which an adaptive procedure was used, using 50 children's spondee words and 6 conditions in which word recognition scores were measured using phonetically balanced kindergarten (PB-K) words. Each child underwent 17 test conditions and the first adaptive procedure was repeated to provide a measure of test-retest reliability. Both the spondee and phonetically balanced words were presented at 65 dB SPL because this was the measured average of teacher's voices in 70 public school classrooms in the Pearson's et al (1977) study.

A single factor repeated measures analysis of variance (ANOVA) was performed separately on both the adaptive procedure and the word recognition conditions to test that there was in fact a measurable difference between the FM system with hearing aids versus hearing aids alone. The results were compelling and indicated the FM + HA condition showed a significant FM advantage, with an 11.8 - 18.4 dB increase in signal to noise ratio over the hearing aid alone for the adaptive condition. In the word recognition procedure, the results indicated that the FM system with personal hearing aids, at a 6 dB SNR, had a better overall score then the hearing aids alone at + 15 dB SNR (Hawkins, 1984)

Overall, the FM advantage over the personal hearing aids alone was equivalent to a + 15 dB improvement in SNR in a typical classroom environment. The hearing aid with the FM system was shown to be a very effective in increasing speech

perception benefits and word recognition scores for hearing impaired, middle school aged children.

Boothroyd and Inglehart (1998) used a within groups design to quantify the benefits of FM system amplification, over hearing aids alone, for 13 teenagers with severe to profound hearing loss. The authors also looked at the increase in recognition of phonemes with the addition of an FM system in a classroom environment. Each child chosen was prelingually deafened, a consistent wearer of hearing aids and FM systems, and attended an oral school for the deaf. The typical classroom environment for these children is not a regular classroom because it has been acoustically modified for severely hearing impaired children and the results may only be relevant for this particular group.

The testing procedure included the recognition of phonemes in a quiet and noisy environment and was scored based on the percentage of phonemes correctly recognized in lists of consonant-vowel-consonant (CVC) words. There were 15 different lists each consisting of 10 words. Phoneme recognition was measured for each child wearing new Phonic Ear BTE's and then with the BTE's and a Phonic Ear FM system with compression limiting. Twelve of the 13 students were fitted binaurally and tone control settings, gains and saturation sound pressure levels were adjusted for maximum audibility. No mention was made however, of which fitting rationale was used and how targets for hearing aids were set. The noise in the classroom was recorded multi-talker babble at 55 dB SPL, indicative of classroom noise, and was produced from 4 loudspeakers placed 4 ft from the room corners to generate a uniform sound field. During the testing, sound level measurements were recorded to ensure room volume level consistency. The test words, in each condition, were produced at 75 db SPL using monitored live voice, and a cloth was in front of talker so the children could not lip read. Using a monitored live voice is more difficult, but is more indicative of how a child would be hearing the teacher in a classroom setting. Each child had to write down as many of the words as they could hear in each aided condition. The noise in the background was 20 dB and 5 dB SNR. These values were chosen by the authors based on their previous research on typical classroom noise levels (Boothroyd and Inglehart, 2004).

A second session occurred 1-2 weeks later for replicability and responses were scored in terms of percent correct for CVC words and all phonemes. The FM benefit was measurable and there was an average of 25 percent improvement in phoneme recognition when wearing both the FM system and hearing aids versus wearing the hearing aids alone. There was not as much effect in noise as the authors had expected. This may be due in part to the extensive acoustic modifications in the classroom that would limit the reverberation and absorb the noise. The results were analyzed using both a pooled single subject and standard group repeated measures ANOVA. Results from this well designed controlled study provided suggestive evidence to show that the addition of the FM system was in fact increasing the speech perception benefits for this group of middle school children.

Anderson and Goldstein (2004) also used a single subject within group design to assess whether there were any improvements in speech perception for eight 9-12 year olds with mild to severe hearing loss. Each child recruited for this study was a long term wearer of hearing aids and was currently enrolled in a mainstream class. The authors wanted to test different types of assistive listening technologies in addition to hearing aids to see if improvements in speech perception could be attained. In this experiment the authors tested the benefits of infrared devices as well, however, only the data from the FM system and hearing aids will be included in the scope of this review.

Each student recruited was subjected to a hearing in noise test wearing their personal hearing aids. Seven students wore analog programmable hearing aids and one wore a digital hearing aids. No hearing aid setting modifications were made and previous fitting of the hearing aids was based on manufacturers' specifications. The conditions for each test included background noise at 10 dB SNR with a 1.1 second reverberation time. The background noise level was a little lower then previous experiments, and the reverberation time a little higher. Fifteen word lists with 50 words per list provided an extensive way to assess the benefits of amplification. In this experiment the children were seated on the floor and a loudspeaker was placed 1.7m in front to mimic what the author's described as an ideal seating arrangement in the classroom. The speech signal was transmitted through a loudspeaker at 70 dB SPL and the noise was at 60 dB SPL coming from loudspeakers to the back and left of the child.

Scores were based on the number of words correctly written down and each list was scored independently by two experienced educational audiologist. Scores of 68.8- 93.3 % were obtained by the children in the hearing aid alone condition in the

classroom environment. When the FM system was used in addition to the personal BTE hearing aids, the percentage scores increased to 86.7 to 100 percent correct. Results of the study were analyzed using one-way repeated measures ANOVA and the results significant. The addition of the FM system accounted for the increase in the speech perception benefit scores for each child. Overall, the participants demonstrated better speech recognition when using an additional signal enhancing device over the hearing aids alone when listening in relatively noisy and reverberant classrooms.

Conclusions

The outcomes from these 3 well designed and controlled studies support the use of personal FM systems in addition to hearing aids over hearing aids alone in a classroom environment. The children with varying degrees of hearing loss all showed improved, and objectively measured, speech perception benefits. Even in noisy and reverberant classrooms, FM systems improved the signal to noise ratio and thus provided additional speech understanding not provided by hearing aids alone. These research findings are limited to two typical classroom environments and one acoustically treated classroom; however the overall compelling results indicate that the average child with hearing loss would benefit from the combined use of both amplification devices.

Recommendations

Although the literature on the benefits of FM systems and personal hearing aids support both technologies together, further research is needed to keep pace with current advances in technology. The research used in this critical review is based on analog hearing aids, except for one child in the Anderson and Goldstein study who wore digital aids, so the audiologist should take this into consideration when prescribing FM systems to children who have the newest digital hearing aids. Each year more advanced hearing aids with state of the art sound processing strategies and noise reduction algorithms are introduced. These hearing aids need to be tested to determine whether or not FM systems, in addition to hearing aids, provide greater speech perception benefits than hearing aids alone.

More research is also needed when the child wears their own hearing aids through the experimental procedure. In most of the reviewed studies the children were fit with new hearing aids and then subjected to testing. There does not appear to be a period where the child can become accustomed to the new hearing aids before they are tested. By allowing the child to keep their own hearing aids, this will be more indicative of how much benefit an FM system is providing. More research is also needed in this area to assess the different fitting rationales, different manufacturers of hearing aids and FM systems, as well as basic versus advanced hearing aids. This will determine what the best strategy is to increase speech perception benefits for hearing impaired middle school aged children.

Finally, although the existing data supports FM system use with hearing aids over hearing aids alone, this research currently pertains to middle school age children and young adults; great language development, and the acquisition of literacy skills, takes place at a very young age and these children should be assessed to determine whether or not an FM system advantage exists for them as well.

Clinicians and educational audiologists should constantly being looking into FM systems for children in classrooms regardless of their degree of hearing loss. Parents and teachers also need to be constantly educated on the benefits of FM system technology and each child should be considered a candidate for an FM system fitting unless shown otherwise.

References

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