Critical Review:
Do Personal FM Systems Improve Speech Perception Ability for Aided and/or Unaided Pediatric Listeners with Minimal to Mild, and/or Unilateral Hearing Loss?

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This critical review examines whether FM devices improve speech perception abilities in unaided and/or aided pediatric listeners with minimal to mild and/or unilateral hearing loss in a classroom environment. Study designs included: single subject with alternating treatments studies and a single group repeated measures design. Overall, the evidence provided by the existing literature suggests that the use of FM devices in a classroom by unaided and/or aided pediatric listeners with minimal to mild and/or unilateral hearing loss does appear to improve speech perception abilities. However, further research is necessary to confirm this trend.

Introduction

Classroom acoustics are important to consider in education. Noise, reverberation, and room modes typically interfere with the ability of listeners to understand speech (Berg et al., 1996). The 2002 ANSI standard on acoustical performance for schools has resulted in a heightened awareness of the effects of background noise and reverberation on student speech perception and learning (Anderson & Goldstein, 2004). The levels of background noise in a typical classroom are often higher than recommended levels, resulting in lower sentence repetition scores (Lewis, 1994).

Many strategies including personal hearing aids, environmental/teaching modifications and assistive listening devices have been used to assist hearing impaired children in the classroom setting (Lewis, 1994). Hearing health care professionals however, have become especially concerned with children who have minimal to mild hearing loss that are not severe enough to warrant the above solutions as beneficial. Children with minimal to mild hearing loss are often treated as if they were children with normal hearing, and must function in reverberant and noisy classrooms with little or no assistance (Johnson & Stein, 1997). Research shows that children with a mild and/or unilateral hearing loss are at greater risk for academic failure, language delays, problematic behavior, increased stress, increased difficulty concentrating, low self-esteem and social difficulties (Tharpe & Bess, 1999).

The lack of beneficial solutions for children with minimal to mild and/or unilateral hearing loss has resulted in the widespread use of educational amplification technology as a possible solution. Personal frequency modulated (FM) devices are used to improve the signal-to-noise (S/N) ratio at the listener's ear level by placing on the teacher a microphone transmitter that delivers an amplified signal over FM radio waves to a receiver device (Anderson & Goldstein, 2004). The receiver delivers the amplified signal to the child in various manners. For children with no amplification, the signal can be delivered directly to the listener's ears by means of headphones, earbuds, or open earmolds (Lewis, 1994). For those fitted with amplification, the receiver is directly coupled to the listener's personal hearing aids. This manner of amplification of the teacher's voice provides a consistent signal regardless of how far the student is from the teacher within the classroom setting (Anderson & Goldstein, 2004). To evaluate the effectiveness of FM systems in a classroom environment for unaided and/or aided children with minimal to mild and/or unilateral hearing loss, this paper includes a review and discussion of three studies.

This critical review examines whether personal FM systems improve speech perception ability for aided and/or unaided pediatric listeners with minimal to mild and/or unilateral hearing loss.

Objectives

The primary objective of this paper is to critically review the existing literature regarding the success of personal FM system use in improving speech perception ability in unaided and/or aided children with minimal to mild and/or unilateral hearing loss.

Methods

Search Strategy

Computerized databases including PubMed, CINAHL, Scopus, and Google Scholar were searched using the following search strategy:

- (children) OR (pediatric) AND (mild) OR (minimal)

OR (unilateral) AND (assistive listening devices) OR
(frequency-modulation systems) OR (FM systems)
AND (speech perception) OR (speech recognition).

Limitations placed on the search strategy include:

- Humans less than 18 years of age; English only articles

Selection Criteria

Selection of studies for this critical review were required to investigate the effectiveness of FM systems on improved speech perception or speech recognition ability tasks in unaided or aided school-aged children with minimal to mild and/or unilateral hearing loss. No limitations were placed on the setting for speech testing, the etiology of hearing loss or outcome measures used.

Data Collection

The results of the literature search generated three articles matching the search criteria mentioned above which will be discussed in this review. These included: 2 single subject with alternating treatments design and 1 single group with repeated measures design.

Results/Discussion

Anderson and Goldstein (2004) used a single-subject alternating treatments design to compare the speech recognition abilities of eight 9-12 year olds with mild to severe hearing loss. The children recruited were educated in general education classrooms and had normal intelligence, language abilities within 1 year of their age peers, and no other disabilities other than hearing impairment. Researchers wanted to test FM systems, infrared devices, and hearing aids to observe potential improvements in speech perception. However, for the purpose of this review, only the data from the FM devices will be reviewed and discussed.

All participants were long time binaural hearing aid users. Each child was required to verbally repeat sentences using the Hearing in Noise Test (HINT) while wearing their personal hearing aids alone to establish baseline performance. The HINT was then repeated using hearing aids in combination with an FM system. The conditions for each test included background noise at 10 dB SNR and a 1.1 second reverberation time. The experiment was performed in a kindergarten classroom, with a simulated teacher 1.7 m in from of the blackboard; typical of a classroom listening environment. The speech signal was delivered by a speaker to a microphone transmitter placed 8.9 cm from the speaker. To objectively evaluate the benefit of amplification with FM devices, there were a total of fifteen word lists; 50 key words per HINT sentence list with a total of 30 sentences.

Scores of each participant were based on the number of words in each sentence that were correctly repeated. Two experienced educational audiologists rated participant responses independently. Interrater response agreement was calculated for 100 percent of the data. A one-way repeated measures analysis of variance (ANOVA) was performed, illustrating a significant effect of FM system use on speech perception in noise.

Results indicated that in a classroom environment with hearing aids alone, participants scored 68.8%-93.3% correct on average. When using a personal FM system in combination with personal hearing aids, participant scores improved to 86.7%-100% correct on average. The FM device with the use of personal hearing aids demonstrated higher speech perception scores overall for each participant.

The researchers concluded that superior performance in speech perception was maintained in the personal FM device plus hearing aids condition. Overall, there were better speech perception scores when using an FM system with personal hearing aids vs. hearing aids alone, while listening in a typical classroom with reverberation and noise.

This article demonstrates support for FM system use with hearing aids in a classroom setting, however due to confounds within the study, the results should be interpreted with caution. Generalization of these results to the population of children who are hard of hearing is questioned due to the small sample size of eight children. The researchers however, state that consistent findings across participants in single-group case series with pre-post testing experiments support generalizations to similar individuals (Anderson & Goldstein, 2004). Vocabulary level of the words used in the HINT is a factor that may influence participant performance. The researchers noted that children with hearing loss typically have gaps in vocabulary as compared to their normal hearing peers. Nonetheless, Anderson & Goldstein concluded that vocabulary issues did not significantly alter conclusions as potential effects of vocabulary were eliminated. Additionally, it is important to emphasize that the children in this study likely presented with worse scores compared to a real-life classroom listening environment. This is due to the fact that background noise was presented as continuous as opposed to interrupted, as in a typical classroom setting. Consequently, when considering the results of

this study for practical application, individual student characteristics and the specific acoustic characteristics of the learning environment need to be considered carefully (Anderson & Goldstein, 2004).

The outcome of this study indicated that in a noisy, reverberant classroom, benefit in speech perception was illustrated when a personal FM system in combination with personal hearing aids was used. Therefore, it appears that a personal FM system will provide listening benefits for children with mild to moderate degrees of hearing loss based on this study's results. Due to the associated limitations and a low level (level 2c) of evidence however, results should be reviewed with caution.

Tharpe, Ricketts & Sladen (2003) conducted a single subject with alternating treatments study to demonstrate the advantages and disadvantages of FM fitting strategies for pediatric listeners between the ages of 5 and 11 with minimal to mild degrees of hearing loss. The Hearing in Noise Test for Children (HINT-C) was used to achieve objective results of these fitting strategies at different azimuths in the presence of noise presented at a fixed level of 65 dBA SPL. Presentation level was adaptively adjusted depending on the participants' response.

To subjectively evaluate participant responses the SIFTER; a 15 item teacher rating form; was administered to the participant's teachers. This questionnaire explored areas of school performance including: academics, attention, communication, class participation, and behavior. In addition, an eight item self-report tool was developed for the purpose of this study to subjectively evaluate fitting strategies. This report queried perception of speech produced by teachers, classmates, and self while wearing the FM (Tharpe et al., 2003).

Fourteen children with minimal to mild permanent hearing loss were used in this study. Researchers used participants with normal cognitive function as determined by their school and parental report. Children were tested in an unaided condition to establish a baseline measure as well as with an FM receiver with no volume control in two configurations and two sound delivery options. FM conditions included: (1) monaurally with an open mold (2) monaurally with a skeleton mold, or (3) bilaterally with an open mold. Participants wore the FM configurations at school for two-week periods prior to speech testing and completion of questionnaires.

Planned pair-wise comparisons and a repeated measures analysis of variance (ANOVA) demonstrated that performance in the unaided condition was poorer than all FM conditions at all signal source locations. Results of the SIFTER data revealed no overall difference between the baseline and FM scores. However, most children were ranked by their teachers as having improved classroom performance in the area of academics when using the FM.
The self-report questionnaire results revealed that the majority of participants liked to wear the FM system because they could hear the teacher better.

The outcome of this study suggests children with minimal to mild degrees of hearing loss demonstrated significantly better speech perception ability in noise when wearing any of the FM configurations as opposed to the unaided condition.

Nevertheless, several study limitations should be addressed including the small sample size of 14 children. This sample size is not necessarily representative of the population of school-aged children. In addition, it must be noted that all speech perception testing was conducted in a sound booth which cannot be directly compared to a classroom setting. However, the researchers assume that speech intelligibility will be considerably improved by the use of this FM system over unaided listening in an academic setting. Five different azimuths were also used to create an environment with surrounding noise similar to that of a classroom setting.

Subjective testing was conducted in attempt to increase the validity of the study. Nonetheless, one variable that could have distorted the findings is the researchers failed to maintain a blind technique with the teachers completing the SIFTER. The teachers were aware of the participant's hearing losses and the fact that the FM system was being used as an intervention designed for better speech perception in the classroom. A placebo-control group of children with non-functioning FM devices would have controlled for this had it been possible within the confines of the study. Tharpe et al. added that the SIFTER and the self-report were not sensitive to subtle changes in FM configuration within the participants.

Additionally, it must be noted that this study was financially supported by a hearing aid manufacturing company; Phonak Inc., which is a potential bias of this study. Therefore, when making conclusions from this study, caution should be taken.

The researchers conclude by stating that it is apparent that children with minimal to mild hearing losses, who are not considered candidates for traditional hearing aids, may benefit from ear level FM devices in the

academic setting. The benefits appear to be in academics, attention, communication and participation in a classroom setting. However, results are suggestive and depend on many other factors. Conclusions should be made with caution as the study provides a low level (level 2c) of evidence.

Hawkins (1984) used a single group repeated measures research method to compare speech recognition in noise for nine children aged 8-14 who had mild to moderate sensorineural hearing loss using various hearing aid and FM system plus hearing aid combinations in a school classroom. This was achieved by objectively measuring performance using two measures: (1) an adaptive procedure to determine the signal to noise ratio necessary for 50 percent performance (2) word recognition scores were attained at signal to noise ratios representing a noisy (+6 dB) and relatively quiet (+15 dB) school classroom. For 11 conditions, the adaptive procedure used spondee words that were presented at 65 dB SPL with the level of speech noise varied in 2 dB steps. In the remaining 6 word recognition conditions, phonetically balances kindergarten (PB-K) word lists were presented through a tape recorder. All testing was performed in a school classroom with a mean reverberation time of 0.6s. Speech signals were delivered from a loudspeaker 2 m from the child located at 0 degrees azimuth. This location for the child was chosen to represent a favorable seating location in the classroom (Hawkins, 1984). Noise was delivered from the speaker 4 m from the child located at 180 degrees azimuth.
Each participant was fitted with Phonic Ear 805 CD behind-the-ear hearing aids bilaterally and was measured with this amplification initially. After performance was measured with the hearing aids, a Phonic Ear 441T FM transmitter and 445R FM receiver with controlled settings was added and this condition was administered to each participant in a random order.

A single factor repeated measures analysis of variance (ANOVA) was performed separately on both the adaptive procedure and word recognition conditions. A significant effect of amplification arrangement was found for both sets of conditions (Hawkins, 1894). The differences between conditions were calculated and analyzed using the Newman Keuls method.

The results illustrated that the largest differences were observed when the FM only conditions were compared to the hearing aid and FM + hearing aid microphone conditions (Hawkins, 1984). The FM only conditions all showed a significant signal to noise ratio advantage over all hearing aid and FM + hearing aid microphone conditions. 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 than the hearing aids alone at + 15 dB SNR (Hawkins, 1984). The mean FM advantage revealed an impressive range of 11.8 to 18.4 dB across comparisons; illustrating that in fact FM only conditions showed a significant advantage over other conditions.

Overall, the outcome of this study lead to the conclusion that for a child with a mild to moderate sensorineural hearing loss, in a noisy, reverberant classroom, the advantage of an FM only over hearing aids alone can be substantial, even when a child has favorable classroom seating (Hawkins, 1984).

However, limitations must be placed on these results due to some weaknesses observed. The testing time for each child was two hours and 30 minutes which may have affected the validity and reliability due to the children's attention span. However, after all 17 test conditions had been completed the first adaptive procedure condition was repeated to provide a measure of test-retest reliability (Hawkins, 1984). A small sample size of 9 was used in the study which makes it difficult to generalize results to this population despite the researchers using controlled test conditions. Additionally, a potential bias was created by the researchers providing compensation to the participants to be a part of the study. To reduce bias during stimuli presentations, the researchers used a tape recorder as opposed to monitored live voice. When evaluating the HA microphone (FM + mic) condition, the researchers noted that the background noise in this study was continuous which is not typical of classroom noise. Also, when a teacher speaks, the level of noise typically decreases; increasing the signal to noise ratio; thus reducing the performance results for the environmental microphone condition in this study.

Due to the limitations associated with this study, and a low level of evidence provided, caution should be taken when interpreting whether speech perception is improved with the use of FM devices in children with mild to moderate hearing loss in a classroom setting.

Conclusion

Based on this limited body of evidence concerning the objective and subjective improvements in speech perception in a classroom setting, it appears that the majority of unaided and/or aided pediatric listeners with minimal to mild and/or unilateral hearing loss may benefit from the use of FM systems. However, the amount of improvement depends on individual characteristics as well as the acoustic characteristics of the learning environment of these children. Despite the

variability seen in the data, it is apparent that children with minimal to mild hearing losses, who are not considered candidates for traditional hearing aids, should be fit with FM devices in educational settings. Unfortunately, due to small sample sizes, a limited number of studies and lack of randomized control trials, caution should be taken when drawing definite conclusions regarding the improvement of speech perception ability with the use of FM systems. Further research is needed to investigate why some children receive more benefit from the use of FM systems than others.

Clinical Implications

From the studies summarized in this literature review, it is clear that FM systems do provide children who have minimal to mild hearing loss with significant potential benefit in an educational setting. Compared to their normal hearing peers, children with hearing impairment require the use of FM technology in their classrooms to allow them to have equal access to verbal instruction (Anderson & Goldstein, 2004). Based on the variability in the data however, it is apparent that personal factors such as attention or attitude, and environmental factors such as classroom acoustics, affect whether or not a child will receive benefit from an FM system. Consequently, when fitting a child with an FM device, Audiologists should use a patient-centered approach and make decisions on a child-by-child basis.
The information gathered in this review can also be useful for teachers and parents of pediatric listeners with hearing impairment, to emphasize the importance of the use of FM devices in classrooms. With this knowledge, teachers and parents can better understand how FM technology may provide these children with improved speech perception, thus potentially improving classroom listening and academic performance.
It must be noted that Audiologists should continue to educate parents and teachers about the proper use, cleaning and maintenance of FM devices as this is important to maintain in order to ensure full potential benefits from this technology.

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