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

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This critical review examines whether FM systems improve speech perception for aided and/or unaided pediatric listeners with mild, fluctuating and/or unilateral hearing loss. Study designs include: single-subject (alternating treatment) combined with survey research, case study and single group pre-post test combined with survey research. Overall, a review of the literature indicates that pediatric listeners with mild, fluctuating and/or unilateral hearing loss have improved speech perception abilities with use of FM systems.

Introduction

Background noise and reverberation at high levels can impact speech perception ability for both normal and hearing impaired children. The levels of background noise in a typical classroom are higher than recommended levels, resulting in lower sentence repetition scores (Lewis, 1994).

Multiple strategies have been employed to assist hearing impaired children in the classroom setting including; personal hearing aids, environmental/teaching modifications and assistive listening devices (Lewis, 1994). While these solutions have proven beneficial for children with moderate to profound hearing losses, many have proven to be inappropriate interventions for children with mild, fluctuating and/or unilateral hearing losses (Lewis, 1994).

With medical advancements in neonatial care, higher rates of otitis media in school aged children, and increased use of ototoxic drugs, specifically cisplatin, mild, fluctuating and/or unilateral hearing losses have increased in prevalence (Tharpe & Bess, 1991). Research shows that children with a mild, fluctuating 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).

Since many traditional treatment and management interventions are inappropriate for this population, Audiologists have turned to the use of FM systems as a possible solution. FM systems are technological devices that transmit a desired signal via FM radio waves to a receiver that can be coupled to the listener's ears in a variety of ways. For listener's fitted with amplification, the receiver is typically coupled directly to the individual's personal hearing aids, whereas the receiver is coupled directly to the listener's ears by means of headphones, earbuds, or open earmolds if the individual is not fitted with amplification (Lewis, 1994). The primary goal of FM systems is to increase the signal-to-noise ratio (SNR) while maintaining a steady input signal (Lewis 1994). Four studies were found and included in this critical review to evaluate whether FM systems improve speech perception for aided and/or unaided pediatric listeners with mild, fluctuating and/or unilateral hearing loss.

Objectives

The primary objective of this review is to critically evaluate the existing literature regarding the effectiveness of FM systems in improving speech perception for aided and/or unaided children with mild, fluctuating and/or unilateral hearing loss.

Methods

Search Strategy

Computerized databases including PubMed, Scopus and Medline were searched with the following search strategy:

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

Parameters were included to limit search results to English only articles with humans less than 18 years of age.

Selection Criteria

Studies selected for this critical review were required to evaluate the overall effectiveness of FM systems in speech perception tasks performed in the soundbooth or in a classroom setting of school-aged children. No limits were set on the type of setting, the child's current

amplification status, the research methods, or outcome measures used.

Data Collection

Results of the literature search produced the following types of articles consistent with the previously mentioned selection criteria: 1 single-subject (alternating treatment) combined with survey research, 1 single group pre-post test combined with survey research and 1 case study.

Results/Discussion

Tharpe, Ricketts and Sladen (2003) used a single-subject with alternating treatments combined with survey research method to examine the advantages and disadvantages of FM fitting strategies for pediatric listeners aged 5 to 11. This was achieved by objectively measuring speech perception in a soundbooth using the Hearing in Noise Test for Children (HINT-C) at different azimuths (angles) in a fixed background noise (65dBA SPL). The children's performance was also subjectively evaluated by the classroom teacher using the SIFTER, a 15 item rating scale used to assess educational performance in areas of academics, attention, communication, classroom participation and behavior. The children were also asked to subjectively evaluate their performance when using the FM system using a questionnaire designed in house for the purpose of this study.

Researchers recruited 14 children with minimal to mild permanent hearing loss. All participants had normal cognitive function as was determined by their school placement and parental report. The children were tested in an unaided condition to establish a baseline measure, and three FM conditions: (1) monaurally with an open mold, (2) monaurally with a skeleton mold, (3) bilaterally with an open mold. The children were required to wear each FM configuration at school for a two-week period.

A repeated measures analysis of variance (ANOVA) and pair-wise comparisons demonstrated that performance in the unaided condition was poorer than all FM conditions. Results from the SIFTER and self-report questionnaire determined no significant difference between the baseline and FM aided scores. However, both teachers and students rated the FM system as providing benefit.

Findings from this study suggest improved speech perception when using the FM system technology in the soundbooth setting (Tharpe et al, 2003). Researchers used controlled testing conditions in an attempt to compensate for the small sample size of 14. The testing environment used in the study does not acoustically represent a typical academic environment; however the researchers presented the background noise at 5 different azimuths in an attempt to simulate real world conditions where background noise is typically surrounding. Tharpe et al. did incorporate subjective questionnaires in an attempt to increase external validity nonetheless a blind technique was not used with the teachers. Therefore classroom teachers were aware of which children were hearing impaired and the benefit FM systems could provide in the classroom setting. The authors' conclude by stating the previously mentioned study limitations, in addition to reporting the inability of the SIFTER and self-report questionnaire to detect subtle changes in FM configuration.

Therefore, based on the results it is reasonable to assume that speech perception improvement will carry over to the academic setting for pediatric listeners with mild, fluctuating and/or unilateral hearing loss, however caution should be taken when making conclusions, as the study provides a low level of evidence.

Paccioretti, Pchora-Fuller and Grotkowski in 1997 used a single group pre-post test combined with survey research method to examine whether pediatric listeners demonstrated improved speech perception with the use of an FM system. At the end of the 2 month trial period each participant's teacher was asked to evaluate the change in the child's classroom performance using a questionnaire developed in house for the purpose of this study (The FM Evaluation Questionnaire). A secondary goal was to determine if speech perception improvement could be predicted from objective and subjective pre-trial measures. A pre-trial soundbooth procedure was used to objectively measure both unaided and aided speech reception thresholds (SRTs) and word discrimination scores (WRSs) in conditions of competing noise (65dBHL). SRTs were determined by the level where 50% of the words were heard. WRSs were determined using a variety of wordlists including; NU6, PBK-50, NU-CHIPS. In the unaided condition WRSs were determined for two competing noise situations: (1) S:N of +10dB (speech presented at 75dB HL and noise presented at 65dB HL) and (2) S:N of 0dB (speech and noise presented at 65dB HL). In the aided condition both speech and the noise were presented at 65dB HL. Speech perception ability was also subjectively evaluated pre-trial by each participant's school teacher using the SIFTER rating scale.

There were 20 participants recruited from the Burnaby, Simon Fraser and/or the Vancouver Health Unit. These children ranged in age from 5 to 13 years and had varying levels of cognitive functioning. The children

were randomly fit with one of two brands of FM systems (Phonic Easy Listener or Telex Sound Enhancement System).

Results of the FM Evaluation Questionnaire showed that 14 of the 18 children evaluated achieved an overall rating of "some improvement" or higher. A matched paired t-test was performed on the results of the pre-trial objective measures. SRT results indicated an improvement in speech perception in 14 of the 20 children. The t-test was calculated to be $t(18) = -7.06$, indicating a significant improvement. WRS results indicated a significant improvement only when the aided results were compared to the S:N of 0 unaided condition. The t-test was calculated to be $t(18) = 4.32$. Results of the pre-trial SIFTER indicated that 79% of the children met the criteria for audiological monitoring or intervention.

The outcome of this study indicated that personal FM systems can improve speech perception for pediatric listeners with lesser degrees of hearing loss for whom conventional amplification is inappropriate and preferential seating insufficient (Paccioretti et al, 1997). Researchers used controlled testing conditions in an attempt to compensate for the small sample size of 20. However, several concerns exist regarding the reliability and validity of the assessment measurements. First, testing was a lengthy procedure therefore the children's attention during testing may be of concern. Secondly, no blinding technique was used for the teachers, meaning the teacher's ratings could have been influenced by their knowledge of the FM system benefit. Lastly, the final evaluation of speech perception improvement was a subjective rating meaning the validity of the results is reliant on the honesty of the respondent. Another concern regarding this study is the lack of correlation between the objective and subjective measures. Subjects who showed benefit in the soundbooth did not always receive proportionally high ratings for improved performance in the classroom.

Therefore, while this study suggests speech perception benefit with the use of an FM system, the study provides a low level of evidence and the assessment instruments were not predicative of degree of benefit; therefore results should be interpreted with caution.

Hawkins (1984) used a case study research method to compare speech perception in noise using a variety of hearing aid and FM system/hearing aid combinations in a school classroom. The procedure consisted of 17 test conditions. An adaptive procedure was used in 11 conditions to determine the SNR necessary for 50% performance using spondaic words. The speech was fixed at 65dB SPL and the noise was varied in 2 dB HL steps. Using the PB-K wordlist the 6 remaining testing conditions used a word recognition procedure. Two different SNR were used: (1) +6dB and (2) + 15dB. All testing was performed in a 7m x 9m x 2.6m school classroom.

Researchers recruited 9 children with bilateral, symmetrical mild to moderate sensorineural hearing losses who were all enrolled in regular classrooms in the public school system. 4 participants were fitted bilaterally with Phonic Ear 805 CD behind-the-ear hearing aids, while 5 participants were fitted with their current amplification to ensure the hearing instrument used in the study provided speech perception scores equivalent or better then the participates current amplification. All children were fitted with a Phonic Ear 441T FM transmitter and 445R FM receiver with controlled settings.

A signal factor repeated measures analysis of variance (ANOVA) was performed separately on both the adaptive procedures and word recognition conditions. The p-value was calculated to be $p<0.00001$ indicating a significant effect. The Newman Keuls method was used to analyze the difference between all possible pairs and conditions. Results indicated that the FM system conditions showed a significant SNR advantage over the hearing aid and FM system + hearing aid conditions.

The outcome of this study indicated that for children with mild to moderate hearing loss, when placed in a traditional classroom where the SNR and reverberation time are less than ideal the advantage of an FM system is substantial (Hawkins, 1984). Researchers used controlled testing conditions in an attempt to compensate for the small sample size of 9, however created a potential bias by providing the participants with monetary compensation for their participation in the study. Reliability and validity was potentially affected by the attention of the children during the lengthy testing procedure, however researchers attempted to improve test-retest reliability by repeating the first adaptive procedure after all 17 test conditions were completed. To further increase reliability and validity 5 of the 9 children used their own hearing aids during the adaptive procedures to ensure the study's hearing aid settings were adequate. All test stimuli were presented via tape recorder, eliminating the bias that exists with monitored live voice**.**

Based on the study's low level of evidence and associated limitations, caution should be taken when interpreting the degree of benefit FM systems can provide for pediatric listeners with mild to moderate hearing loss.

Conclusion

Although there is a limited number of studies, the present findings suggest that the majority of children with mild, fluctuating and/or unilateral hearing losses may benefit from the use of FM systems; however the amount of benefit varies based on the personal (attention, personality, etc) and environmental factors (preferential seating, distance, classroom acoustics, etc) for each child. While all children should be fit with an FM system when hearing loss is a concern, more research is required to determine why some children receive more benefit from an FM system than others and why a mismatch exists between objective and subjective research methods. Future research should include larger sample sizes and randomized control trials in order to determine the effectiveness of FM systems in improving speech perception for aided and/or unaided pediatric listeners with mild, fluctuating and/or unilateral hearing loss.

Clinical Implications

Results indicate that FM systems have the potential to provide pediatric listeners with significant benefit in the classroom setting. However, based on the variability in test results, it can be assumed that personal and environmental factors play a major role when determining appropriate treatment and management strategies for this population. Therefore Audiologists working with this population should take into consideration the multiple factors when selecting and fitting amplification.

Another factor to consider is equipment malfunction and inappropriate use. FM systems will not provide adequate amplification if the unit batteries are dead, the unit setting is in the off position and/or if the unit is not synced with the listener's amplification. Therefore a daily inspection should be performed on all FM system equipment to ensure functioning. Furthermore, prior to the use of equipment one should recommend all parents, children and teachers be initially trained and receive ongoing guidance and counseling to supplement the process.

References

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