FM Systems for Children with Minimal to Mild Hearing Loss

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Introduction

In the past two decades, much has been learned about the speech perception and psychoeducational difficulties experienced by many children with minimal and mild degrees of hearing loss. In the 1980's, it was revealed that children with unilateral hearing loss are at risk of academic failure at a rate ten-times that of their normal hearing peers (Bess and Tharpe, 1984, 1986; Oyler and Matkin, 1988). More recently, children with other configurations of minimal sensorineural hearing loss were found to experience more difficulty than children with normal hearing on educational tests and functional health measures of behavior, energy, stress, social support, and self-esteem (Bess, Dodd-Murphy, and Parker, 1998).

Clear documentation exists of the speech perception in noise difficulties encountered by children with minimal hearing loss (Bess, Tharpe, and Gibler, 1986; Crandell, 1993). One form of intervention commonly recommended for children with minimal and mild degrees of hearing loss is the use of FM amplification (Bess et al., 1998). The purpose of these systems is to enhance the desired signal (typically the teacher's voice) above the background noise in the classroom. There are several factors that need to be considered when fitting FM systems on this population. Of primary concern, is that children in the academic setting need to hear their teacher's voice with as little competition as possible. There is no doubt that FM systems provide improved signal-to-noise ratios (SNRs) in noisy classrooms and enhance the ability of children to hear their teacher's voice. Based on what is known about the benefits of bilateral hearing aid use, common sense would suggest that a bilateral FM configuration would provide maximum benefit to a child when listening to a teacher. However, there are situations in the educational environment when children not only want to hear their teacher's voice clearly, but also want to hear comments made by their classmates. The ability to hear the comments of classmates has both academic and social implications. This would suggest that, for those with minimal to mild hearing losses, coupling one ear via FM to receive the teacher's voice and leaving the other ear open (i.e., not occluded by an earmold and FM receiver) to receive speech from classmates might be a reasonable compromise.

Earmold style is another important consideration when fitting FM systems. For listeners with minimal hearing loss, the more occluding the earmold, the greater the attenuation of background noise; however, occluding earmolds may contribute to an unnatural perception of one's own voice. That is, increasing occlusion is often associated with complaints of a sensation of fullness in the ears and an echo-like perception commonly referred to as the `occlusion effect'.

The purpose of this study was to demonstrate the advantages and disadvantages of FM fitting strategies for children with minimal to mild degrees of hearing loss. The effects of monaural versus bilateral fittings and different sound delivery options (i.e., earmold type) were examined.

Method

Participants

Fourteen children (ten boys and four girls) between the ages of five and eleven years (mean age = 8 years) were enrolled in this study. All children had

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minimal to mild permanent hearing loss defined according to one of the following three criteria: (1) pure tone average (PTA) > 25 dB but < 45 dB HL bilaterally; (2) thresholds of $ 25 dB HL at two or more frequencies above 1000 Hz bilaterally; or (3) unilateral hearing loss $ 45 dB HL PTA. Children with bilateral minimal to mild hearing loss comprised 57% (N = 8) of the cohort while 21% (N = 3) had unilateral hearing loss, and 21% (N = 3) had high frequency losses. The average PTA of the poorer hearing ear across subjects was 34 dB HL.

Participants had normal cognitive function as determined by their school placement in general education classrooms and parental report. Twenty-one percent of the participants had been required to repeat a grade in school and 14% had received or were currently receiving resource assistance. They were each placed in classrooms with 16 to 29 additional students with traditional seating arrangements (either rows or grouped seating).

Procedures

Participants were fit with an ear level FM receiver (Phonak Microear) with no volume control in two configurations (i.e., monaural and bilateral) and with two sound delivery options (i.e., skeleton and open mold). Specifically, participants were fit (1) monaurally with an open mold, (2) monaurally with a skeleton mold, or (3) bilaterally with an open mold. Because the skeleton mold was more occluding than the open mold, it was not considered reasonable or ethical to fit a child in skeleton molds bilaterally. The transmitting microphone (Phonak Campus S) was set in directional mode.

Participants were tested in each FM condition plus an unaided condition. The order of these fitting conditions was randomly selected and participants wore the FM configurations at school for two-week periods prior to speech perception testing, completion of teacher questionnaires, or self-reporting.

Speech Perception

All speech perception testing was conducted in a double-wall, sound-attenuating test room having a reverberation time (averaged across frequency) of 450 ms. Lists from the Hearing in Noise Test for Children (HINT; Gelnett, Suminda, Nilsson, and Soli, 1995) were presented via loudspeaker (Tannoy System 600) under four listening conditions in a background of noise. This loudspeaker uses fused concentric drivers resulting in a point source sound location. The transmitting microphone was positioned six inches from the speaker emitting the speech signal. Listening conditions consisted of the primary speech signal located at 0 , 90 , 180 , or 270 azimuth with five additional noise sources (uncorrelated speech-shaped noise) at all locations not being utilized by the speech signal plus 135 and 225 . That is, if the speech signal was located at 90 , the noise sources were located at 0 , 135 , 180 , 225 , and 270 , and if the speech signal was located at 0 , the noise sources were located at 90 , 135 , 180 , 225 , and 270 , etc. This resulted in obtaining four threshold signal-to-noise ratios (SNR) for each FM configuration for a total of 16 SNRs. The noise-emitting speakers were of bi-polar design (Definitive Technology BP-2X).

The participant's task was to repeat the sentences spoken by a male talker in the presence of noise presented at a fixed level (65 dBA SPL at the participant's ear). Correct identification of each sentence was based on proper repetition of key words as specified in the test manual. Scoring was accomplished for ten-sentence blocks. A SNR was calculated as that necessary to achieve 50% correct performance. Presentation level of the sentences was adaptively adjusted depending on the participant's response (an incorrect response raised the level, and a correct response lowered the speech level for the next presentation) per author recommendations.

Teacher Questionnaire

The Screening Instrument for Targeting Educational Risk (SIFTER; Anderson, 1989) was administered to the teachers of the participants prior to fitting the child with an FM, and following each two-week trial period with an FM configuration, for a total of four administrations. The SIFTER is a short, 15-item teacher rating form designed to provide a valid method by which children with hearing problems can be screened educationally. Several areas, or subtests, of school performance are explored including academics, attention, communication, class participation, and behavior. The SIFTER has been field tested and shown to have good content and score reliability (Anderson, 1989).

Self-report

An eight-item self-report tool was developed for

Table 1. Self Report of Participant Perceptions of FM Use

1. When wearing this FM system, how easy was it to understand people talking?
   Very easy   Easy   O.K.   Hard   Very Hard
2. When wearing this FM system, how did the teacher's voice sound to you?
   Very easy   Easy   O.K.   Hard   Very Hard
3. When wearing this FM system, how did the voices of the other kids in your class sound to you?
   Very easy   Easy   O.K.   Hard   Very Hard
4. When wearing this FM system, how did your voice sound to you?
   Very easy   Easy   O.K.   Hard   Very Hard
5. Do you like wearing the FM system? Why or why not?
6. Can you think of times when the FM system was helpful?
   On the final visit,
7. Which did you like the best, wearing the FM system on one ear or two?
8. Which did you like the best, wearing the open earmold or skeleton mold? (the child is shown examples of each earmold)

this study and all questions can be viewed in table 1. The self report queried perception of speech produced by teachers, classmates, and self while wearing the FM; general wear ability; and comparative desirability across configurations. The self-report was completed by every participant after each two-week trial with an FM configuration for a total of three self-reports.

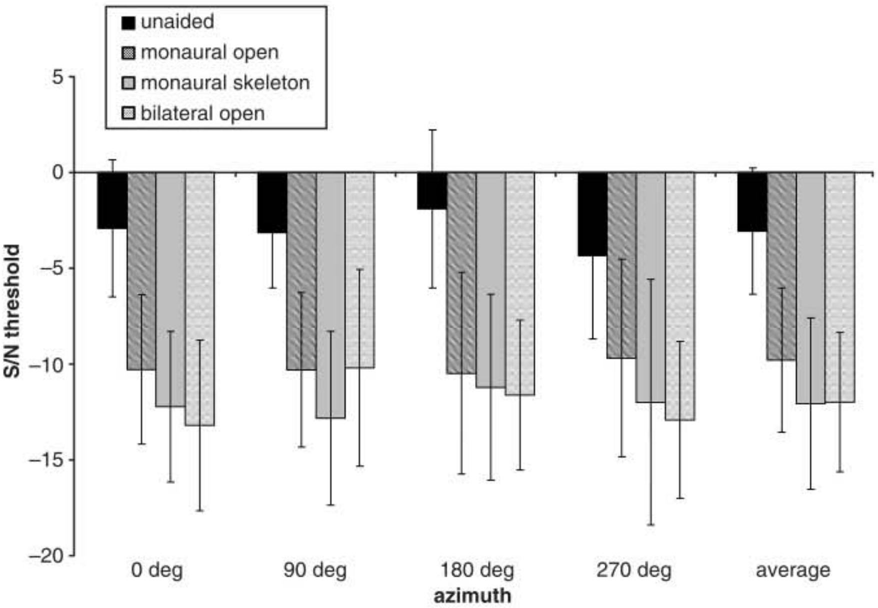

Figure 1. HINT results (in signal-to-noise ratio; SNR) for participants at the four signal source locations (in degrees azimuth) and on average across source locations. Results were obtained with three FM configurations (monaural with open earmold, monaural with skeleton earmold, and bilateral with open ear mold) and in an unaided condition.

Results

Speech Perception

The results obtained from the HINT-C are represented in figure 1. Recall that the dependent variable for this task was the threshold signal-to-noise ratio (SNR) and the lower the SNR, the better the performance. As shown in this figure, performance in the unaided condition was poorer than all FM conditions at all signal source locations.

A repeated measures analysis of variance (ANOVA) yielded a significant main effect of configuration (monaural skeleton, monaural open, bilateral open, or unaided), $F(3,30) = 16.59$, $p = .00$. This main effect of configuration appeared to be driven primarily by the unaided condition. Effect of signal source location was not significant. Examination of only the FM conditions yielded no significant effect of configuration. Planned pair-wise comparisons demonstrated that performance in the bilateral open earmold condition was superior to that of the monaural open earmold condition with signal source locations of 0 , F(1, 11) = 5.96, p = .03, and 270 , F(1, 11) = 4.76, p = .05. Bilateral versus monaural performance differences were not significant at 90 or 180 .

Teacher Questionnaire

Figure 2 summarizes the SIFTER data for the children whose teachers returned the questionnaire (N = 10). Recall that the SIFTER was administered prior to initiating the FM trials (baseline) and following each two-week trial with a specific FM configuration for a total of four administrations. However, we found that the teachers were unable to identify differences among the three FM configurations (monaural with open mold versus monaural with skeleton mold versus bilateral with open mold) using the SIFTER. Therefore, only the results from the baseline and last SIFTER administrations are presented here. As illustrated, higher scores (i.e., better ratings) were obtained on four of the five SIFTER subtests following the FM trial than prior to the FM trial (unaided). The teachers' responses on the SIFTERs were subjected to an ANOVA, which demonstrated no overall difference between the baseline and last SIFTER scores. However, planned pairwise comparisons demonstrated that the participants were ranked by their teachers as having improved classroom performance in the area of academics, F(1,9) = 7.36, p = .02, when using the FM.

In addition to examining the raw SIFTER scores, it was of interest to scrutinize the SIFTER scores of those children who were ranked by their teachers as having the most classroom difficulty prior to starting the FM trial. Specifically, figure 3 illustrates the percentage of participants who acquired either marginal or failure scores for the five subtests prior to participating in an FM trial (baseline) and at the end of the six-week trial period (last SIFTER). Note that a lower percentage of participants exhibited failure or marginal ratings on all five of the subtests following the FM trial than on the baseline administration of the SIFTER. In fact, the number of participants scoring at the failure or marginal level (collapsed across all five SIFTER subtests) dropped from slightly over half (54%) to slightly over a quarter (26%).

Finally, because these are preliminary data with a small number of subjects, we compared our baseline findings with those of Bess et al. (1998). The cohort evaluated by Bess et al. (1998) consisted of 66 children with minimal sensorineural hearing loss. As seen in figure 3, the baseline findings of the current study compared well to the results of Bess et al. (1998) suggesting that our cohort was representative of the larger subject pool. That is, 54% of the participants in the current study and 52% of those in the study by Bess et al. (1998) scored in the marginal or failure category on the SIFTER.

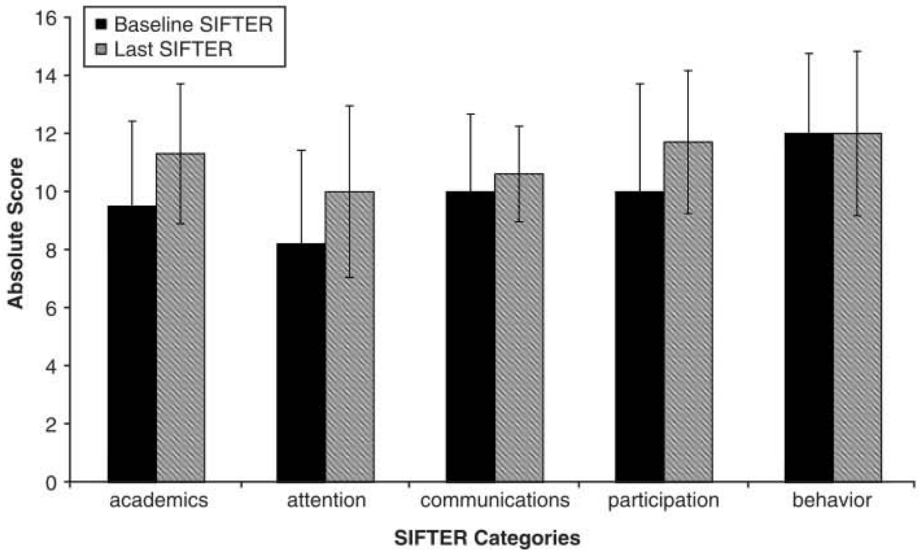

Figure 2. Average SIFTER scores for each of the five subtests obtained prior to initiation of the FM trial (baseline) and at the end of a six-week trial with FM amplification (last).

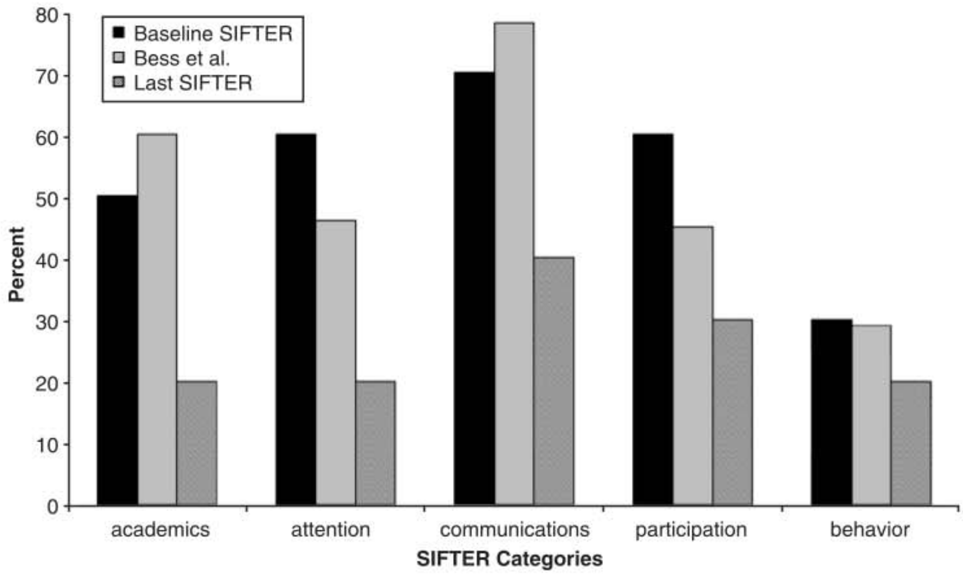

Figure 3. Percentage of participants whose scores were in the marginal or failure range for subtests on the SIFTER prior to receiving FM fitting (baseline) and at the end of a six-week trial with FM amplification (last). The Bess et al. (1998) data are included for comparison purposes.

Self-report

Recall that the participants' self-report of speech perception and ease of wearability while utilizing the FM in the classroom consisted of eight questions. Participants were unable to make reliable distinctions among the three FM configurations. Therefore, the results of the last self-report administered at the end of the six-week FM trial are reported here. Note that some children answered I don't know to some of the questions.

When asked When wearing this FM system, how easy was it to understand people talking? , 64% of the participants responded very easy or easy , and 23% reported O.K. . When asked When wearing this FM system, how did the teacher's voice sound to you? , 90% of the participants responded very easy or easy . When asked When wearing this FM system, how did the voices of the other kids in your class sound to you? , 18% reported hard or very hard , 49% reported O.K. , and 13% reported easy . When asked, When wearing this FM system, how did your voice sound to you? , only 21% reported very easy or easy ; almost half of the participants (46%) reported O.K. .

Seventy-four percent of the participants reported that they liked wearing an FM system because they could hear the teacher better. Of those who did not like to wear the FM, comments were made such as I can only hear the teachers and not my friends or The FM is itchy . The participants were able to cite specific times during the school day when they noted the benefits of FM use such as when the other kids get loud , when the teacher was reading Winnie the Pooh , and just before recess when everyone gets real loud . All of the participants preferred wearing one FM receiver rather than two and all but one participant wanted to keep the FM system at the conclusion of the study. The vast majority of the participants (90%) could not cite a preference for the use of a skeleton versus an open earmold.

Discussion

The purpose of this study was to examine the speech perception benefits of wearing various configurations of an ear level FM system by children with minimal to mild degrees of hearing loss. In addition, it was of interest to determine the desirability of the various configurations as perceived by the children and their teachers. As expected, 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. In fact, on average and collapsed across configurations, there was an 8.3

dB SNR advantage in the FM versus no-FM condition. A previous study using HINT materials demonstrated that a difference of 1 dB on this adaptive task corresponds to an 8.9% difference in sentence intelligibility by adult listeners (Nilsson, Soli, and Suminda, 1996). However, the design used for the current study included multiple competing noise sources in a moderately reverberant room. Therefore, it is anticipated that our sentence intelligibility curve would not be as steep as that of the Nilsson et al. study. Nonetheless, although the listening conditions in a laboratory setting cannot be directly compared to those in a classroom, it is reasonable to assume that speech intelligibility will be considerably improved by the use of this FM system over unaided listening in an academic setting.

Bilateral FM placement resulted in significantly better speech perception scores than monaural placement only when the sound source was located at 0 or 270 azimuth. These results remain somewhat baffling as the transmitting FM microphone was always placed 6 inches from the speech signal source. Therefore, the signal level received by the child participant remained consistent across the signal source locations. In addition, sources were calibrated to ensure that the total competing noise level at the position of the child's head was identical across the various conditions. Therefore, it is assumed that SNR was approximately constant across all FM conditions at the position of the head. An explanation for the variable results across speaker configurations is evident when considering the potential effects of fairly open earmolds in the presence of minimal hearing loss. That is, the level of direct sound energy in the ear from individual speakers will vary depending on the speaker angle. It is well known that the open ear canal is not equally sensitive to sounds arriving from all angles (e.g,. Beck, 1983). Therefore, the SNR in the ear canal was not expected to be identical across all conditions. By moving a speech speaker from an angle of greater sensitivity to an angle of lesser sensitivity, while in turn moving a noise source to the angle of greater sensitivity, the SNR in one ear can be affected. In addition, the binaural advantage may also be affected because the intensity level difference between the two ears for the speech signal will also change.

The SIFTER findings in this study were consistent with findings of other studies examining the academic status of children with minimal to mild degrees of hearing loss (Bess et al., 1998; Bess and Tharpe, 1986; Oyler and Matkin, 1988). Of particular interest, however, was the decrease in marginal and failure ratings in each of the five SIFTER categories by children with minimal to mild losses after a six-week trial with FM amplification. However, it must be pointed out that we failed to maintain a blind technique with the teachers completing the SIFTERs. That is, the teachers knew that the children enrolled in the study had hearing loss and that the FM systems were an intervention designed to improve the children's ability to hear in the classroom. It was not possible within the confines of this study to set up a placebo-control group of children with non-functioning FM devices.

The results of the self-report were of particular interest. Anyone who has worked with school-age children knows of the concerns expressed by this age group about appearances. It is often difficult to convince children to wear anything that might make them look different from their peers whether it is nonconformist clothing, eye glasses, braces, or, in this case, a FM system. However, the overwhelming majority of children enrolled in this study liked the ear level FM device and opted, with their parents' permission, to purchase the system at the end of the study. Although they were unable to state their reasons, the children who wanted to keep the FM system wanted a monaural configuration.

In conclusion, several study limitations should be addressed and caution should be used in the interpretation of these data. The subject sample is small and these findings represent preliminary data. Additional data are being gathered and will be reported in a future publication. Furthermore, as stated previously, the teachers who provided the SIFTER ratings were not blind to the hearing status of the participants nor were they blind to the expected benefits of FM system use. There is a need for future studies of this type to maintain a blind technique for the administration of such tools. Finally, the SIFTER and the self-report were not sensitive to subtle changes in FM configuration with this group of young, school-age children. Despite these limitations, however, 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.

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Participant Survey