The FM Advantage in the Real Classroom

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The present study examined the benefits of students using personal FM systems in their own classroom and in the home. Eleven students aged between 5 and 15 years participated in the study. All participants had a sensorineural hearing loss ranging in degree from moderate to profound. During the study, the students used the FM system combined with their hearing aid at school and at home for three months. Performance was documented using measures of oral language comprehension in the student's daily classroom combined with self-report measures obtained from the parents, teachers and students. Results indicated a significant benefit for the use of the FM system combined with the hearing aid over the hearing aid alone in the real classroom. Parents and students reported a significant benefit for use of the FM system at home. Teachers, parents, and students identified an improvement in specific situations of need. This study supports the recommendation of combining a personal FM system with the student's hearing aid to improve speech understanding in school and in the home.

Key words: FM systems, classroom, school children, assistive listening devices

Introduction

Classrooms are auditory-verbal environments, where instruction is presented to the children by the teacher through spoken communication. Optimal access to the target signal is a requirement for learning in classrooms today (Flexer, 1997). This means that children need to listen to obtain new information. Therefore, in order for children to learn, they need optimal access to the target speech signal. A barrier to accessing this auditory information is background noise (Flexer, 1997). Background noise affects speech recognition, academic performance, reading and spelling skills, concentration, attention, and the behaviour of all children, whether they have normal hearing or a profound hearing impairment (Crandell & Smaldino, 2000).

Typically, the ambient noise of a classroom ranges from 41-51 dBA (Crandell & Smaldino, 1994), compared with internationally recommended ANSI standards of 30-35 dBA (Ehrlich, 2003). The crucial aspect to consider when investigating background noise is the signal-to-noise ratio (SNR). SNR is the ratio between the intensity of the speaker's voice to the intensity of the background noise. This ratio is an important determinant of speech understanding. As the SNR decreases or worsens, speech understanding decreases (Hawkins & Yacullo, 1984). In typical classrooms, the SNR ranges between +1 and +3 dB (Crandell & Smaldino, 2000), compared with international recommendations of a SNR of +15 dB.

Classrooms are also reverberant environments. Reverberation is when sound is reflected, so that the reflections of previous sounds mask and smear the energy in the speech signal. Due to this masking, speech understanding decreases when there is a long reverberation time (Nabelek & Robinson, 1982). Schools have reverberation times that are often greater than 1.2 seconds, which is significantly greater than the recommended ANSI standard of 0.6 seconds (Ehrlich, 2003). It is clear that classrooms are not reaching the standards recommended by ANSI (Ehrlich, 2003), and children are denied the optimal acoustic environment in which to access information to learn.

To create a favorable listening environment within a classroom, SNR needs to be increased by enhancing the teacher's voice, reducing background noise and reverberation, and decreasing distance. Although decreasing background noise is not always possible, enhancing the teacher's voice and decreasing the effects of distance can be accomplished by a personal FM system. Personal FM systems combined with a hearing aid lessen the negative effects of background noise and distance by utilizing a wireless microphone that is six inches from a teacher's mouth and transmits the teacher's voice directly to a receiver via FM radio waves. With a personal FM system, the child wears the receiver attached to his or her hearing aid and there is a direct input into the hearing aid from the FM system (Berg, Blair, & Benson, 1996).

In view of the theoretical benefit of the use of FM systems in the classroom, a number of researchers have studied if the benefit is realised. Research has focused on the use of FM systems as a solution to overcoming or lessening the challenges of background noise, distance, and reverberation and increasing the SNR. Based on this research, the use of personal FM systems has been recommended as a solution to providing increased access to the target speech signal at school and at home. The first study to examine the efficacy of FM in the home was Moeller and colleagues (Moeller, Donaghy, Beauchaine, Lewis, & Stelmachowicz, 1996) who investigated the efficacy of the use of personal FM systems at home over a two-year period for preschool-aged children with hearing loss ranging in degree from mild to severe. According to the daily log completed by the parents, FM systems were worn in adverse listening conditions. Six of the ten children participating in the study demonstrated increased rates of language acquisition as measured by an increase in grammatical complexity. Subjectively, effective communication also improved in a variety of listening situations, as there was a decrease in the requests for clarification for children using FM systems. Use of the personal FM system was inconsistent throughout the day due to practical problems of bulkiness, interference, and device complexity. Many of these issues have been solved with new technology of ear-level receivers, multiple channels, and ease of switching between FM + microphone and FM only. The ability to use FM + microphone can aid in the use of these systems by allowing the input from the hearing aid microphone to be utilised as well throughout the day (Moeller, et al. 1996).

More recently, research has focused on demonstrating the benefit of FM systems in classrooms. Unfortunately, most studies were based in laboratories or simulated classrooms. Three studies have, however, been completed in classrooms: One with children with normal hearing in a real classroom using a soundfield FM system (Arnold & Canning, 1999), one with children with hearing impairment ranging between mild to severe in a real classroom with a teacher simulated by a loud-speaker (Anderson & Goldstein, 2004), and one study with children with severe-to-profound hearing impairment in a classroom designed for children with hearing impairment using a personal FM system (Boothroyd & Inglehart, 1998). In each of these studies, the use of FM amplification was statistically significant and children demonstrated improved oral comprehension and speech understanding.

In the first study (Arnold & Canning, 1999), children with normal hearing aged eight to eleven years old used a soundfield FM system in one classroom. A comprehension test was used to measure the advantages of the FM system. Benefit was demonstrated by comparing two conditions, FM and no FM. A loudspeaker was positioned at the front of the classroom where the teacher usually stood and at about the teacher's height. Differences in comprehension between the two conditions were statistically significant, with the FM condition resulting in higher comprehension (Arnold & Canning, 1999).

The second study (Anderson & Goldstein, 2004) investigated the use of personal FM in a typical kindergarten classroom, which is representative of classroom listening environments. Eight children aged nine to twelve years with mild to severe hearing impairment participated. Personal FM systems were utilised with hearing aids and were set to use the FM signal and the microphone from the hearing aid. A loudspeaker was placed 1.7 meters in front of the blackboard to simulate a teacher speaking. The children listened to a sentence level speech understanding test in quiet and noise. Significant benefit was demonstrated by the use of the personal FM system (Anderson & Goldstein, 2004).

In the third study (Boothroyd & Inglehart, 1998), 13 adolescents with severe-to-profound hearing aged 15 to 17 years used a personal FM system combined with hearing aids. Speech was delivered by live voice with the FM transmitter speaker 12 inches from the speaker's mouth. Each child used a personal FM system and was seated 10 feet from the speaker in a classroom acoustically treated for children with hearing impairment. Consonant-vowel-consonant words were spoken with multitalker babble generated from four loudspeakers placed in the four corners of the room. Significant benefit in speech understanding was demonstrated when using the personal FM system.

The present study advances the current body of research, provides insight to the benefits of utilising a personal FM system in the classroom and at home, and extends the finding of previous studies of FM system benefit to the real classroom. This is accomplished by documenting the benefit of FM through the assessment of oral language comprehension (i.e., understanding language at a paragraph level, rather than speech understanding at a word or sentence level). The child's teacher and classroom noise were also utilised instead of taped speech and/or noise from microphones. The measure of oral comprehension coupled with the teacher's real voice and classroom noise provides greater ecological validity, or the extent to which findings can be generalised to the real world. The ecological validity is increased with an oral comprehension test as children need to understand and comprehend language presented orally to them in their own classroom environment.

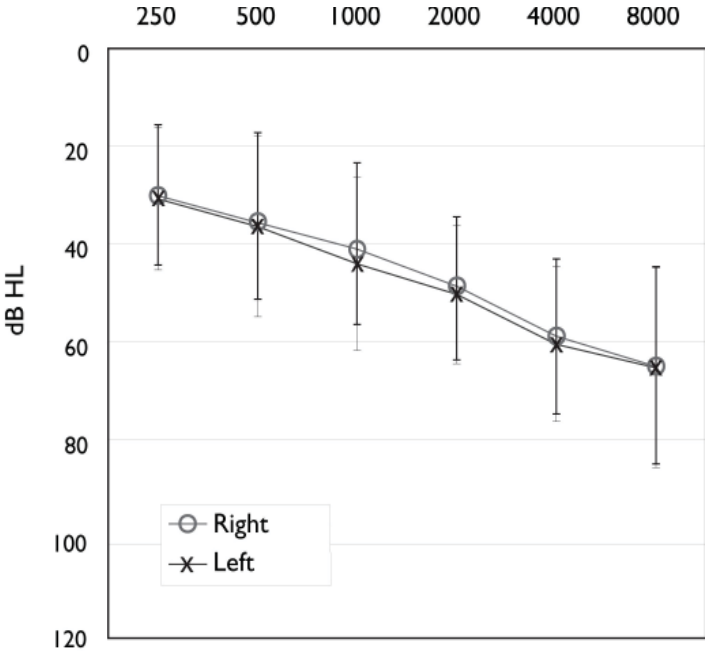
Method

Participants

Eleven students aged 5 years, 11 months to 15 years, 2 months (mean age 11 years, 0 months) participated in the current study. All students were fit binaurally with digital hearing instruments for at least six months, were oral language users, attended mainstream schools, and were able to complete open-set speech recognition in aided auditory alone conditions.

The hearing losses of the students ranged from moderate to profound sensorineural hearing loss. In the right ear, the mean unaided pure-tone average (500, 1000, and 2000 Hz) was 66.1 dB HL and in the left ear, the mean unaided pure-tone average was 59.2 dB HL (Figure 1). This range of hearing loss is consistent with the guidelines for the National Deaf Children's Society (NDCS) in the UK for fitting FM systems. Students with left-corner or reverse sloping hearing losses were not included in the study. Eight of the 11 students had experience with FM.

Figure 1. Mean audiogram with standard deviations for 11 participants.



Equipment

FM equipment. The students used a personal FM system with their own hearing instrument for three months in their everyday lives. The FM system used was the Oticon Lexis system, composed of ear-level receivers and a handheld transmitter. The handheld transmitter has three modes of directionality: Omni-directional, focus, and super focus. The ear level receivers include a gain trimmer that allows the FM response to be adjusted in relation to the hearing instrument's microphone response.

The FM system was fitted to each hearing aid following the Modernising Children's Hearing Aid Services (MCHAS) guidelines. The MCHAS FM fitting protocol of FM advantage was used (Evans, 2002). This fitting method ensures maintenance of the FM advantage and insurance of well-functioning hearing aids. The FM signal for a 65 dBSPL input was balanced to the hearing instrument's signal for a 65 dBSPL input. Fitting was verified with electroacoustical measurements of the hearing aid and the hearing aid coupled to the FM system. The output curve of the hearing aid coupled to the FM system from an input signal of 80 dBSPL was higher than the output curve of the hearing aid from an input signal of 65 dBSPL. This resulted in an FM advantage of the FM system over the hearing aid. The student received the microphone input and FM input at equal levels.

Assessments. Each participant's receptive vocabulary, speech production, and speech perception were assessed to ensure that test performance on the oral comprehension measure was not affected by limitations in language knowledge or speech perception skills. *The British Vocabulary Picture Test* (Dunn, Dunn, Whetton, & Burley, 1997) was administered to assess receptive vocabulary. Assessment of speech production was accomplished through a phonological analysis completed by the student's speech and language therapist. Finally, the Manchester Junior Words test (Watson, 1957), an open-set word identification test, was administered to assess speech perception abilities. These results also ensured that the students' hearing aids were functioning well. The results from the testing are listed in Table 1.

Table 1. Students' speech perception, speech production, and receptive vocabulary performance prior to FM trial.

Students	Speech Perception*	Speech Production	Receptive Vocabulary**
1	93%	All Correct	119
2	93%	All Correct	92
3	100%	All Correct	89
4	93%	All Correct	46
5	100%	All Correct	86
6	100%	All Correct	104
7	79%	All Correct	116
8	100%	All Correct	117
9	100%	All Correct	111
10	50%	Unintelligible	50
11	100%	All Correct	85

* Percent whole word correct; ** Standard Score

FM benefit was assessed objectively and subjectively by using an oral modification of a reading comprehension test [Neale Analysis of Reading Ability-Revised (NARA II), Neale, 1997] and two questionnaires, respectively. The questionnaires were the Children's Home Inventory for Listening Difficulties (CHILD) (Anderson & Smaldino, 2000) and the Children's Outcome Worksheet (COW) (Williams, 2003).

The NARA II consists of a set of graded passages for testing the rate, accuracy, and comprehension of oral reading. There are two forms of graded passages with each form consisting of six levels and a practice passage. The student is instructed to read a passage aloud. The comprehension of each passage or story is measured by a set of questions. The number of questions ranges between four (Level 1) and eight (Levels 2-6). The difficulty between the levels increases by the number of sentences per passage, conceptual level of the passages, and nature of the questions that are asked. The questions are targeted at more abstract concepts as the level increases. For example, a Level 1 question is "Where did the bird hop to?" and a Level 6 question is "What do people think causes the birds to migrate in this way?" During the current study, the test was adapted to meet the needs of assessing the benefits of FM. Instead of the student orally reading the passage, the teacher of the deaf read the passage to the student seated six feet away.

The *CHILD* contains two checklists (student and parent version) with listening situations that occur in a student's home environment. Fifteen situations are described and then each one is rated on a scale of one ("Huh?") to eight ("Great") for listening success on the "Understand-O-Meter."

The COW, based on the C*lient Oriented Scale of Improvement*

(COSI) (Dillon, Birtles, & Lovegrove, 1999), is a questionnaire that aids in identifying specific listening needs in different settings, from the perspective of the parents, students, and teachers. Each individual identifies situations in which it is believed there is a need for the student to hear better. After identifying the situations, they are rated in order of importance by each individual.

Procedure

Speech perception, speech production, and receptive vocabulary were assessed at the beginning of the research project. The speech perception test (*Manchester Junior Words*) is an open-set word identification test. The words were read aloud to the students by their teacher of the deaf using live voice at 60 dBA. A phonological analysis at the word level was completed by the student's speech and language therapist. The speech and language therapist also administered a receptive vocabulary test (*British Vocabulary Picture Test*).

The benefit of FM use was assessed objectively and subjectively through the use of the oral comprehension test and questionnaires. During the three-month period, the students used the FM system at school and at home. Parents, teachers, and students all commented on the use of the FM system and its benefits through the questionnaires.

The level of noise in the classroom, as measured by a sound level meter, varied between 55 and 80 dBA during "quiet" work time with students The reverberation time ranged between 0.3 to 0.5s (mean 0.4s) (Broughton, 2001).

After ten weeks of use of the FM system, a reading comprehension test, the *NARA II* was administered in the classroom by the student's teacher of the deaf on the side of the classroom six feet away from the student while the class engaged in quiet table work. The distance was based on the average distance the classroom teacher was from the student during periods of classroom lecture.

The *NARA II* was modified from an oral reading test to a spoken comprehension test. It was read aloud by the student's teacher of the deaf while the student sat six feet from the teacher. The teacher's voice (direct signal) was 55 dBA at the student's desk, which was measured continuously throughout the testing. A passage was read and then the teacher asked the student questions about the content of the passage. The student listened to a passage presented in the FM + microphone mode and with hearing aids only. The order of listening with the FM and with hearing aids only was counterbalanced across subjects.

Form #1 and Form #2 of the test were used with each student. One of the forms was used with the FM and the other form with hearing aids only. This was also counterbalanced across subjects. As the test was modified, a starting point, or basal level, and ending, or ceiling, level was determined. To establish the basal level, the student needed to achieve 100% accuracy for a level in the hearing-aids-only (HA) condition. The test was discontinued when 50% accuracy was achieved for a level in the HA condition by the student.

The use of FM also was assessed subjectively through questionnaires: the *CHILD* and the *COW*. The students completed their questionnaires with the assistance of their parents or the teacher of the deaf. Each questionnaire was completed before FM use began and after the three months of FM use. The first administration of the questionnaires focused on benefit from the hearing aid while the second administration focused on the benefit from the FM system.

When completing the *CHILD*, which includes 15 different listening situations, the parents reported how well the student responded in each situation and the students responded as to how well they could hear and understand in each of the situations. Both respondents used the "Understand-O-Meter," which rates perceived listening success on a scale of 1 to 8, with larger numbers indicating greater success.

On the second questionnaire, the *COW*, parents, students, and teachers identified between one and five specific situations in which there was a need for the student to hear better. These situations are ones in which the parent, teacher, and the student him- or herself wanted to understand more. Following the three month period of using the FM system, the teacher, parent, and student rated the degree of change and subsequent listening ability with the FM system.

Results

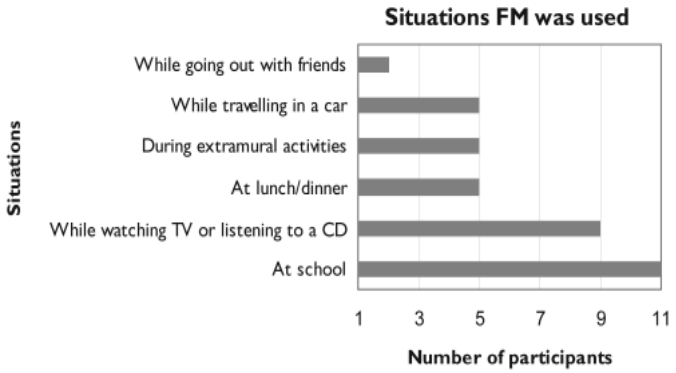
Eight of the 11 students used the FM system more than four hours per day in a variety of situations with three students using the FM system for a few hours at critical times (Table 2). The overall use of the FM system was less when compared to their hearing aid use, as the FM system was mainly used during specific situations in which benefit was perceived. Expectations for the use of FM are for it to be used in noisy environments. The students were not in noisy environments throughout their entire day.

Table 2. Amount of use of the FM system by student.

Students	Hours of Use of FM	Hours of Use of HA
1	A few hours every day	8 hours
2	A few hours every day	8 hours
3	8 hours	8 hours
4	4-8 hours	8 hours
5	4-8 hours	8 hours
6	4-8 hours	8 hours
7	4-8 hours	8 hours
8	A few hours every day	8 hours
9	4-8 hours	4-8 hours
10	8 hours	8 hours
11	4-8 hours	4-8 hours

The FM was used by all students at school. Common situations in which the FM system was used outside of school included watching TV or listening to music CDs. The specific situations in which the FM system was used are shown in Figure 2.

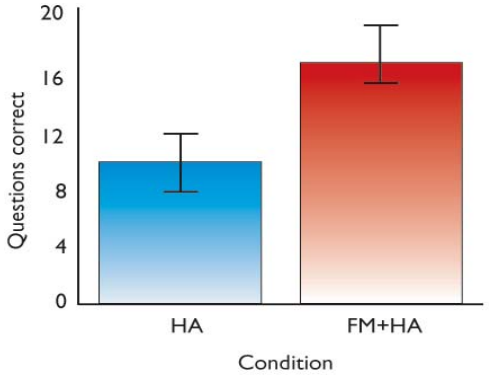
Figure 2. Situations in which FM was used.



Oral Comprehension (NARA II)

The mean oral comprehension score for the HA condition alone was 10.9 (SD: 2.0) whereas the mean score for the FM+HA was 17.1 (SD: 2.6). A paired t-test indicated that the difference in oral comprehension performance between the HA and FM+HA condition was significant (t= 4.59, df= 10, p<.001), indicating a significant improvement in oral comprehension performance in the FM+HA condition. These results are shown in Figure 3.

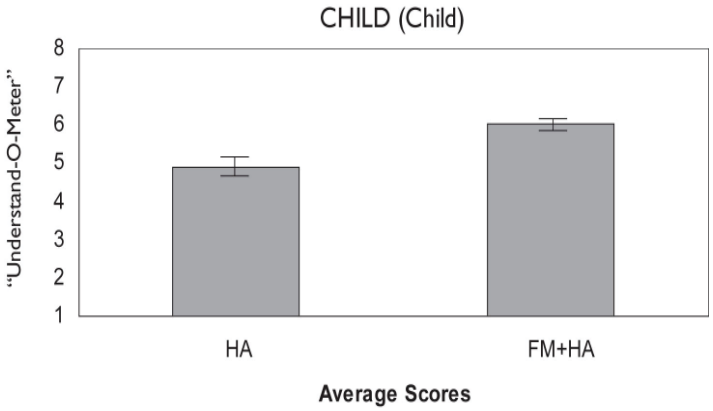
Figure 3. *NARA II* mean scores and standard error for HA and FM+HA conditions



Listening Situational Benefit

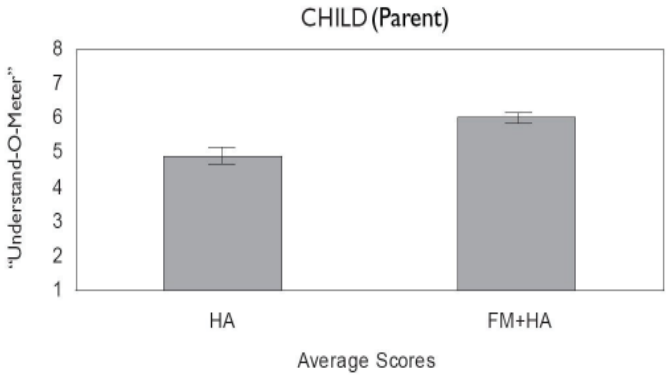
Children's Home Inventory for Listening Difficulties (CHILD). The checklist identifies areas of strengths and weaknesses that the student experiences in understanding in different situations. The *CHILD* can be re-administered to evaluate the benefit of amplification within the home environment. Because some of the items in the *CHILD* are not applicable to FM use (e.g., use of an alarm clock or radio to wake up), these items were not addressed by some subjects. Therefore, the overall mean scores on the questionnaire were used for analysis rather than total item-by-item scores. Students' mean scores for the FM+HA condition (mean: 6.0, SD: 0.4) and HA condition (mean: 4.9; SD: 0.3) were significant different (t= -2.49, df= 10, p<0.05) (Figure 4).

Figure 4. Mean and standard errors for the subjects responses to the *CHILD* in HA and FM+HA conditions



In addition, the parents' mean scores for the students' under the FM+HA condition (mean: 5.8; SD: 0.4) and HA condition (mean: 4.8; SD: 0.4) also were significantly different (t= -2.43, df= 10, p<0.05) (Figure 5). Therefore, results indicated a significant improvement in functional listening skills at home in the FM+HA condition over the HA alone condition.

Figure 5. Mean and standard errors for the parent's responses to the *CHILD* in HA and FM+HA conditions



Analysis of the *CHILD* identified seven situations as ones in which the student experiences listening difficulty. Five were identified by the students and six by the parents, with four overlapping. These situations are listed in Table 3.

Table 3. Results of t-tests comparing FM+HA and HA alone conditions on specific items of the *CHILD*

Situation	Parent	Child
1. At dinner table, question from across table	.003*	
2. Quiet room, spoken to without person getting child's attention first	.027*	.035*
3. Understanding TV speech or conversations	0.048*	
4. TV/Noisy toy, spoken to from behind	0.020*	0.045*
5. Called from another room	.021*	.029
6. Playing inside with a group of children (noise)		.037*
7. Listening from backseat of a car	.003*	.047*

Numbers represent p values obtained. *statistically significant at the p<.05 level

Four of the 15 situations included in the *CHILD* were not suitable to evaluate the use of FM. These situations included "sitting side by side in a quiet room," "the student using a clock radio or alarm to wake up," "speaking on the telephone," and "talking to the student in a quiet room." Parents and students identified these as situations in which FM did not provide benefit and they did not respond to them for the FM+ HA condition.

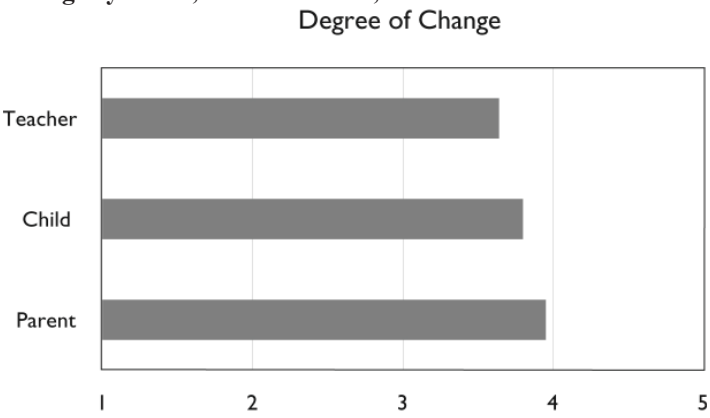
Children's Outcome Worksheet (COW). Parents, teachers, and students identified specific situations in which they wanted the student to hear better (Table 4). These situations fall into four of the categories in the *COW*: "Conversation with group in noise," "Hearing teacher in the classroom," "Hearing students in the classroom," and "Hearing speakers at a distance."

Table 4. Specific situations identified by at least five parents, student, and/or tachers on the *COW* as in need of improvement prior to FM use.

Situations	Parent	Student	Teacher
Home	During a meal	During a meal	
	Talking with others during a family or friend gathering		
		Hearing others' answers or comments	
School	Instructions	Lecturing	General Instructions
		Group work	Group work
		Assembly	Assembly
		Social activities	Social Activities

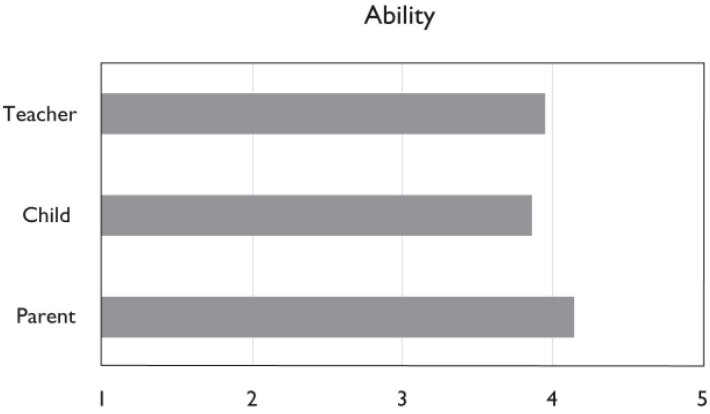
After 12 weeks with the new amplification (in this case FM use), the degree of change in each situation was rated on a five-point scale from "Worse" (1) to "Much Better" (5) by the parent, student, and teacher. Students, parents, and teachers generally rated the use of the FM system as 'Much Better' in the situations they identified (Figure 6).

Figure 6. Degree of change percieved from using the FM system, as measured by the COW. 1=Worse, 2=No difference, 3=Slightly better, 4=Much better, 5=Much better



The frequency with which each student could hear satisfactorily was rated on a scale from "Hardly Ever" (1) to "Almost Always" (5). The parents, students, and teachers rated the use of the FM system to increase the ability of their student to hear satisfactorily 'Most of the Time' in the situations they identified (Figure 7).

Figure 7. Ability to hear with the FM system, as measured by the COW. 1=Hardly ever (19%), 2=Occasionally (25%), 3=Half of the time (50%), 4=Most of the time (75%), 5=Almost Always (95%)



Discussion

The current study examined the benefits of using FM in the student's own classroom and at home. Increased ecological validity was achieved with use of an oral comprehension test that was administered by the student's teacher of the deaf in the student's own classroom during quiet work time. In addition to a measure of oral comprehension, standardised question-

naires were administered before the study and after three months of FM use to demonstrate perceived benefit of the use FM. This approach builds on previous research that demonstrated the benefits of FM when the teacher's voice and classroom noise conditions were simulated (Arnold & Canning, 1999; Anderson & Goldstein, 2004; Boothroyd & Inglehart, 1998) and at home with non-standardised questionnaires (Moeller et. al., 1996). The previous studies in the classroom presented materials from a loudspeaker designed to simulate either the teacher or background noise. This research expands the combined focus of these studies and provides more documentation on the benefits of FM at school and at home.

The objective measures used in the current study were completed in the students' classrooms. It is imperative for the student to receive benefit from the FM system in their own classroom, as this is where learning takes place. The objective measure of oral comprehension is one which allows inferences to be made more easily to how children will comprehend information that is given in the classroom (Arnold & Canning, 1999). Children need to access spoken information in order for comprehension to occur (Flexer, 1997).

The results from the oral comprehension tests demonstrate the superiority of the FM + HA condition over the HA only condition. The significant difference between using FM + HA and using the HA alone indicates that there is a large benefit from using FM + HA in the classroom with students with hearing impairment. This extends the findings from previous research that also indicates benefit from using FM (Arnold & Canning, 1997; Moeller, et al., 1996; Boothroyd & Inglehart, 1998; Anderson & Goldstein, 2004).

Using an oral comprehension test allowed for a more ecologically valid approach to assessing benefits of personal FM in the student's classroom and further supported the previous research with children with normal hearing (Arnold & Canning, 1997). There are, however, limitations of using an oral comprehension assessment, as it was not able to assess other auditory demands placed on a student in the class environment. For example, following directions and group conversations were not directly assessed. However, these were indirectly assessed through self-report questionnaires.

Demonstrated benefit from the use of FM at home is essential, as this is where children develop and learn language. Activities that children participate in outside of school provide language input. These activities usually are associated with unfavorable listening environments and a poor SNR. For children to be able to access the language stimulation, a positive SNR needs to be available. Incidental learning is a large part of how children learn; however, poor acoustical environments do not allow the required access to language. FM use can aid in providing a better acoustical environment, therefore providing access to language.

The subjective measures demonstrated benefit from the use of FM as well. Previous research (Moeller et. al., 1996) used subjective measures that indicated benefit from the use of FM. However, the questionnaires used in their study focused on the student's perceptions and did not investigate the benefits that parents and teachers may have perceived.

The results in this study from the *CHILD* demonstrated a significant FM advantage for the students at home. The parents' responses also demonstrated a significant benefit from the student's use of FM at home. For the jointly-identified situations, there were several situations in which both the parent and student perceived benefit from the use of the FM system.

The *CHILD* is a questionnaire designed to assess the benefit or need of amplification; therefore, four of the situations in the *CHILD* are not applicable for the use of FM amplification, but are more applicable for the use of identifying situations that may be difficult for a student and demonstrate the need for amplification. There is a need to develop measures specifically to measure the benefits of FM in the home environment. There are such measures for measuring the benefits of FM in the school environment for example, the *Listening Inventory for Education [(LIFE);* Anderson & Smaldino, 1996].

The *COW* is a client-oriented scale. This allows for a more open format and addresses the individual needs of the participants. Therefore, the specific needs and benefits of FM may be identified better with the *COW* than with the *CHILD* because the *CHILD* is a tool designed to identify listening difficulties in the home and not to be used as a pre/post measure. In this study, the *COW* indicated a significant benefit from the use of FM+HA versus HA alone.

The age range of the students in the present study is broad, which may have impacted the results. Therefore, there was a need for different testing methods and assessments. The effect of differing language abilities was controlled by using testing methods and assessments that were appropriate for the ages of the students in the study. The objective and subjective measures used in this study were appropriate for the age of the students: The *NARAII* has normative data for students aged 6 to 12 years old. Therefore, all students were able to participate in the objective testing. The *CHILD* was developed for students aged 3 to 12 years; however, a suggested age to begin the questionnaire with children is 7 to 8 years. The one student that was younger than seven years old (5 years, 11 months) was able to complete the questionnaire with assistance from their teacher of the deaf. The *COW* was developed for children aged 4 to 12. All students were able to identify situations in which they felt they needed to hear well. Therefore, although the age range used in the present study is large, it is unlikely that this wide age range is a confounding factor to our results.

Another possible impact of the large age range used in this study is that age might have affected the degree of benefit from FM use, with younger students experiencing less FM benefit than older students. Because a child's auditory system is not fully developed until adolescence, increased SNR is required for younger children (Nozza, 1999, Fallon et al., 2002). However, there was only a small difference between students aged ten years and younger (average FM benefit of 17.4) and students over ten years (average FM benefit of 16.8) in the present study.

The data presented demonstrates the benefits obtained from the use of an FM system in children's daily lives. The use of FM systems increased the students' ability to understand information in the classroom and outside of the classroom. FM systems are

used at school during lectures, group work, and in assembly. At home, the use of FM systems also was found to be beneficial during activities such as eating dinner and listening in a car.

Further research is needed to expand this body of knowledge to more children with hearing impairment across the ages and to investigate additional benefits of the use of FM systems at school and at home in daily life. Research into the use of FM systems with children with cochlear implants has not been documented, despite the fact that children with cochlear implants also require a positive SNR and therefore should also benefit from the use of FM technology. Furthermore, research systematically investigating the effect of age on the use of FM systems is needed. The present study did not demonstrate an effect of age on FM benefit; however, the number of subjects was not large enough to investigate this topic sufficiently. A more in-depth investigation of the speech and language development of children who use FM systems versus those who use hearing aids alone also is also needed.

In summary, children with hearing impairment require the use of an FM system to access the target signal, the teacher's voice. The present study supports and expands on the previous research documenting the benefits of FM (Arnold & Canning, 1997; Boothroyd & Inglehart, 1998; Moeller et al., 1996; Anderson & Goldstein, 2004). In the classroom, the students' oral comprehension was significantly higher when an FM system was utilised. This result clearly supports the need for the use of an FM system for a student with a hearing impairment. Additionally, the students and their families rated the use of the FM system as significantly beneficial in activities outside of the classroom. This finding indicates that an FM system can provide success in the student's home environment as well as in the classroom. Therefore, FM systems should be recommended as an option for all students with a hearing impairment.

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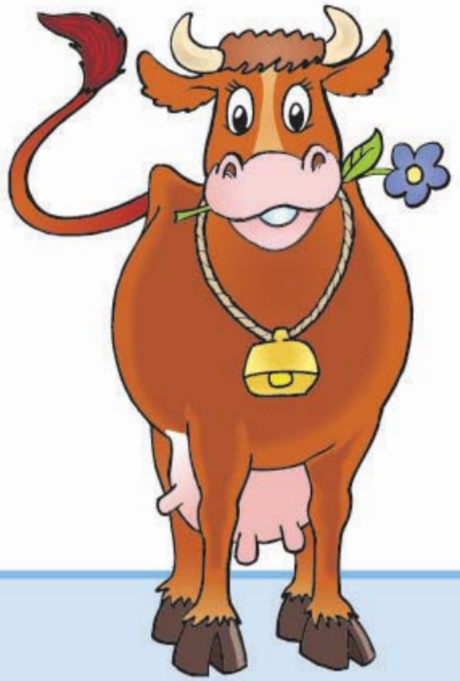
COW The Children's Outcome Worksheets

Name: _____

Client Number: _____

Audiologist: _____



Categories

1. Conversation with 1 or 2 in quiet
2. Conversation with 1 or 2 in noise
3. Conversation with group in quiet
4. Conversation with group in noise
5. TV/Radio/Movies at normal volume
6. Familiar speaker on phone
7. Unfamiliar speaker on phone
8. Hearing phone ring from another room
9. Hearing front door bell or knock
10. Hearing traffic
11. Hearing teacher in the classroom
12. Hearing children in the classroom
13. Hearing family in home
14. Hearing family in car
15. Hearing speakers at a distance
16. Other

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oticon
PEOPLE FIRST

the Child's Needs

COW

Name: _____

Audiologist: _____

Date: **1. Needs established** _____

2. Outcome assessed _____

SPECIFIC NEEDS	Indicate Order of Significance ↓
Understanding others when in a car. Specific Situation:	☐
Understanding TV/Radio at normal volume levels. Specific Situation:	☐
Understanding conversation in distracting noise. Specific Situation:	☐
Understanding others in large group (i.e. lunchroom, assembly, playground, gymnasium). Specific Situation:	☐
	☐

CATEGORY	Degree of Change "Because of the new hearing instrument, I now hear..."						Ability (with hearing instrument) "I can hear satisfactorily..."					
	Worse	No Difference	Slightly Better	Better	Much Better	SCORE	Hardly Ever 10%	Occasionally 25%	Half the time 50%	Most of time 75%	Almost Always 95%	SCORE
	1	2	3	4	5		1	2	3	4	5	
				AVG.						AVG.		

the Teacher's Needs

COW

Name: _____

Audiologist: _____

Date: 1. Needs established _____

2. Outcome assessed _____

SPECIFIC NEEDS	Indicate Order of Significance ↓
Understanding directions in presence of competing noise. Specific Situation:	☐
Understanding teacher and classmates in group discussions. Specific Situation:	☐
Understanding classmate presentations or stories. Specific Situation:	☐
	☐
	☐

CATEGORY	Degree of Change "Because of the new hearing instrument, child now hears..."						Ability (with hearing instrument) "Child can hear satisfactorily..."					
	Worse	No Difference	Slightly Better	Better	Much Better	SCORE	Hardly Ever 10%	Occasionally 25%	Half the time 50%	Most of time 75%	Almost Always 95%	SCORE
	1	2	3	4	5		1	2	3	4	5	
				AVG.						AVG.		

the Parents' Needs

COW

Name: _____

Audiologist: _____

Date: **1. Needs established** _____

2. Outcome assessed _____

SPECIFIC NEEDS	**Indicate Order of Significance** ↓
Understanding directions in classroom and home. Specific Situation:	☐
Understanding conversation with competing noise. Specific Situation:	☐
Understanding room to room conversation. Specific Situation:	☐
	☐
	☐

Degree of Change
"Because of the new hearing instrument, child now hears..."

CATEGORY	Worse	No Difference	Slightly Better	Better	Much Better	SCORE
	1	2	3	4	5	
				AVG.		

Ability (with hearing instrument)
"Child can hear satisfactorily..."

Hardly Ever 10%	Occasionally 25%	Half the time 50%	Most of time 75%	Almost Always 95%	SCORE
1	2	3	4	5	
			AVG.		