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CLASSROOM USE OF FM SYSTEMS WITH HEADSETS BY CHILDREN WITH MILD, FLUCTUATING, OR UNILATERAL HEARING LOSS

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ABSTRACT

Twenty school-age children with hearing loss that was minimal (16 to 25 dBHL) to mild (26 to 40 dBHL), fluctuating conductive, or unilateral were fit with personal FM systems with lightweight headsets for a two-month trial period in their classrooms. At the end of the trial period, the classroom teacher evaluated change in the child's classroom performance. This measure was used to evaluate the success of the trial. Prior to the trial period, the classroom teacher completed an evaluation of the child's classroom performance, and the children were tested by an audiologist in the soundbooth in unaided and aided conditions. The pre-trial measures were considered for their possible value in predicting which children would be successful users of the equipment. The FM system with headset was found to be beneficial for about 80% of the children. However, there was no single pre-trial indicator or combination of indicators that could be used to predict who would or would not be a good candidate for long-term use of the equipment. These findings suggest that before making a final decision regarding the suitability of an FM system with headset for use by a child, it is necessary to consider pre-trial factors (type of classroom, classroom behavior, academic performance, audiometric results, and personal factors), as well as evidence gathered during a trial period. Furthermore, since most children showed some benefit from the signal-to-noise enhancement provided by the equipment, another long-term strategy may be to design classrooms which are less acoustically hostile. A cost-benefit analysis of these alternatives should be undertaken.

ABRÉGÉ

Vingt enfants d'âge scolaire ayant une perte auditive conductive fluctuante, ou une perte unilatérale allant de minimale (16 à 25 dBHL) à légère (26 à 40 dBHL), furent équipés de systèmes individuels à modulation de fréquence et d'écouteurs légers pour une période d'essai de deux mois dans leurs classes. À la fin de la période d'essai le professeur évalua les variations de la performance en classe de chaque enfant. Avant le début de la période d'essai, le profeseur évalua également la performance scolaire de l'enfant et un test auditif, avec et sans amplification, fut administré à chaque enfant par un audiologiste. Pour prédire quels enfants pourraient bénéficier de l'usage de cet équipement il a été tenu compte du potentiel prédictif des mesures préalables à l'essai. Le système à modulation de fréquence avec écouteurs s'est révélé bénéfique pour environ 80% des enfants. Par contre il a été impossible de trouver un seul indicateur préalable à l'essai, ou un groupe d'indicateurs, qui permette de prédire qui pourrait être ou non un bon candidat pour utiliser cet équipement. Ces résultats suggèrent qu'il est nécessaire de tenir compte aussi bien des facteurs préalables à l'essai (genre de classe, comportement en classe, performance scolaire, résultats audiométriques et facteurs personnels), que des preuves amassées durant la période d'essai avant d'établir une décision finale sur le bien fondé de l'utilisation par un enfant d'un système à modulation de fréquence et écouteurs. Étant donné que la plupart des enfants ont bénéficié de l'amélioration du signal par rapport au bruit, il est suggéré qu'une autre stratégie serait de concevoir des salles de classe moins hostiles sur le plan acoustique. Il serait bon d'entreprendre une étude des coûts par rapport aux bénéfices apportés par cette autre solution.

1. INTRODUCTION

There are hearing-impaired children in schools today for whom hearing aids and traditional FM systems would not usually be recommended. These include children with the following kinds of hearing loss: minimal or slight hearing loss (16 to 25 dBHL); unilateral hearing loss; and fluctuating conductive hearing loss. Due to the nature of their hearing problems, these children may experience little difficulty in ideal listening conditions; however, they may have difficulty understanding speech in the unfavourable listening conditions typical of classrooms.

In classrooms, communication is primarily auditory-verbal, with visual information supplementing spoken information. Information is presented in spoken language with the presumption that students can hear what the teacher says. It has been noted that children spend at least 45% of the school day engaged in listening activities (Berg, 1987). Listening is often mentioned by teachers as a crucial skill for classroom success (Flexer, Wray & Ireland, 1989). In addition, children are expected to participate in interactive communication activities where difficulties in listening are likely to jeopardize the appropriateness and acceptability of their contributions.

In a recent study by Crandell (1993), children with minimal sensorineural hearing loss obtained poorer sentence recognition scores than normal-hearing children in most listening conditions. As listening conditions became more adverse, the performance of both groups declined, but the decline was more marked for those with minimal hearing loss. Therefore, we would expect that even children with only a minimal hearing loss will experience difficulty understanding speech in noisy conditions. Furthermore, it has been noted by Bess (1986) that a mild or unilateral hearing loss can cause significant academic problems.

Berg (1993) points out that in a typical classroom it is not uncommon for background noise levels to reach 55 to 75 dBA when a teacher and 25 or more students are present. He further states that for students to hear effectively, the noise levels for an occupied classroom should not exceed 40 to 50 dBA. Besides background noise, other factors, such as signal-to-noise ratio, reverberation time, and the distance between the listener and the talker may further undermine the quality of transmission of the speech signal, with listeners consequently experiencing further difficulty understanding speech.

Preferential seating, or having the child sit as close to the talker as possible, has often been recommended as a means to overcome the poor listening conditions of the classroom. Such preferential seating, however, is insufficient to overcome the adversity of the acoustical conditions in the classroom. Flexer and her colleagues (1989) stated that although a hearing-impaired child may detect the teacher's voice and perceive the teacher's intonation patterns, the fine detail of individual speech sounds may still not be heard clearly enough to allow the child to differentiate one word from another. The negative effects of a typical classroom environment on the integrity of the speech signal have been demonstrated by Leavitt and Flexer (1991). Using the Rapid Speech Transmission Index (RASTI) System to measure the effect of a quiet listening environment on a speech-like signal, they obtained results indicating that, even when a child is seated in a front-row seat, the loss of critical speech information can be significant.

In the absence of architectural solutions to improve classroom acoustics, the use of assistive listening devices, such as a personal FM system, offers a way to enhance signal transmission for a listener. Historically, FM systems have been fit on children with severe-to-profound hearing loss and used as either a primary source of amplification or as a supplement to a personal hearing aid fitting. Recently, personal FM systems with lightweight headphones have been recommended for use in the classroom by children with minimal, fluctuating, or unilateral hearing loss (Crandell, 1993; Cargill & Flexer, 1991; Kopun, Stelmachowicz, Carney & Schulte, 1992; Maxon, 1992).

When an FM system is used in a classroom situation, the teacher wears a microphone that picks up his or her voice at close range. The acoustic speech signal is converted to an FM signal that can be transmitted across the room to a child wearing an FM receiver. The received signal is then converted back to a sound signal that is delivered over the headset. There are two advantages of using an FM system: the amount of speech energy that is lost due to transmission of the signal over distance is minimized, and the FM-transmitted signal is not degraded like an acoustic signal would be degraded during transmission through a noisy and highly reverberant classroom. Note that the FM systems in question differ from traditional FM systems because they provide little or no amplification of the signal. Moreover, in contrast to traditional FM fittings, FM systems with headsets do not eliminate the listener's reception of signals from other sources (Kopun et al., 1992). For example, the teacher's voice can be transmitted from the other side of the classroom by the FM unit while, at the same time, the child is still able to hear the voice of a nearby classmate.

A study was undertaken in Spring 1994 in the Lower Mainland area of British Columbia to assess the use of personal FM systems with headsets by hearing-impaired school-aged children who were not considered, according to existing provincial ministry guidelines, to be candidates for either hearing aids or traditional FM systems. Some children had previously tried amplification and rejected it.

The objectives of the study were to determine: 1. whether students would demonstrate improvement with the equipment on measures of classroom performance based on teacher observations; 2. whether benefit could be predicted from pre-trial measures obtained from teacher evaluations or audiologic measures; and 3. to make recommendations regarding the possible inclusion of FM with headset into an established protocol within the Auditory Training Equipment Program of the provincial Ministry of Education.

Table 1. Profile information about the children who participated in the study and the equipment fit on them

Child	Age	Grade	First Language	Hearing Loss	Exceptionality	Equipment
1	6	K*	English	permanent conductive		Telex
2	5	K*	English	mixed bilateral		Phonic Ear
3	5	K*	English	fluctuating conductive		Telex
4	7	1	English	fluctuating conductive	Down Syndrome	Phonic Ear
5	6	1	English	unilateral sensorineural		Telex
6	6	1	Chinese	bilateral sensorineural		Telex
7	6	1	Chinese	bilateral sensorineural		Telex
8	7	2	English	bilateral sensorineural	"gifted"	Phonic Ear
9	8	2	English	unilateral sensorineural		Phonic Ear
10	8	2	English	fluctuating conductive		Telex
11	9	3	English	mixed bilateral	Down Syndrome	Phonic Ear
12	8	3	English	fluctuating conductive	Down Syndrome	Telex
13	9	4	English	bilateral sensorineural	"gifted"	Phonic Ear
14	10	4	English	bilateral sensorineural		Phonic Ear
15	12	5	English	unilateral sensorineural	Vision Deficit	Telex
16	10	5	English	bilateral sensorineural		Telex
17	11	6	English	bilateral sensorineural	Learning Disabled	Phonic Ear
18	12	7	English	fluctuating conductive		Phonic Ear
19	13	7	English	permanent conductive		Telex
20	13	8	Chinese	bilateral sensorineural		Phonic Ear

* Kindergarten

2. METHOD

2.1 Participants

Twenty hearing-impaired elementary school children participated in the study (Table 1). Criteria for participant selection were: 1. bilateral minimal-to-mild hearing loss from .500 to 3 kHz, a fluctuating mild-to-moderate or unilateral hearing loss; 2. no current use of any amplification or assistive listening device in the classroom or at home; 3. consent of the child, parents, and teacher. Any child seen for an educational audiology assessment at the Burnaby, Simon Fraser, or Vancouver Health Units within the one-month intake period of the project who met the selection criteria was included. Ages ranged from 5 to 13 years and grades ranged from kindergarten to grade 8. Three of the children were learning English as a second language and five had additional disabilities, including Down Syndrome, visual impairment, and learning disabilities. Two children were identified by their teachers as being "gifted". The heterogeneity of the group is representative of the children with the kinds of hearing loss of interest who were enrolled in elementary schools in the district.

2.2 Equipment

Two commercially available personal FM systems, a Phonic Ear Easy Listener (PE300T transmitter, PE300R receiver with AT606 Walkman-style headset), and a Telex Sound Enhancement System (TW6AA transmitter, AAR-10 receiver with GenEXXA HP-110 light-weight headphones) were used for aided performance measures in the soundbooth and for the classroom trials. Both systems were set to provide signal enhancement but not amplification. The Phonic Ear system was set with output compression having a kneepoint of 78 dBSPL such that no compression was expected for normal speech input. The Telex system was set with the compression off. Two different brands of FM systems with headsets were used because our intention was to evaluate the general type of system and not to evaluate any one brand or to compare brands.

2.3 Design of the Study

All children were recruited and underwent a pre-trial audiologic evaluation at one of the three participating clinics within a one-month intake period at the beginning of the final term of the school year. The regular classroom teacher of each child completed a pre-trial evaluation of the child's classroom performance. The children then underwent a two-month trial with one of the two brands of FM system with headset[1]. An equal number of each of the two brands were fit, with the brand being randomly assigned to the child (Table 1). Benefit from the use of the device was evaluated post-trial based on the teacher's subjective rating of change in the child's classroom performance.

2.4 Procedures

Pre-trial Soundbooth Clinical Procedures. Children were evaluated by routine methods in one of the government audiology clinics in the Greater Vancouver Regional District. Special procedures to evaluate the performance of the children with the FM system with headset included a comparison of their unaided and aided speech reception thresholds (SRTs) and their unaided and aided speech discrimination scores measured in the soundfield in conditions of competing noise.

SRTs for spondee words presented in noise (with competing 8-talker babble presented at 65 dBHL) were obtained by determining the level of presentation of the speech at which the words were heard 50% of the time. The stimuli were those described by Cheesman (1992).

Speech discrimination scores, the percentage of monosyllabic words in a list that were correctly identified by the listener, were obtained unaided in the soundfield under two conditions of competing noise: 1. at a signal-to-noise ratio (S:N) of +10 dB (speech presented at 75 dBHL; noise presented at 65 dBHL); 2. at a S:N of 0 dB (speech presented at 65 dBHL; noise presented at 65 dBHL).

The sources of signal and babble were arranged to simulate diotic rather than dichotic listening conditions. Specifically, the speech signal always originated from a loudspeaker located at 0^0 (directly in front of the child) and the competing babble always originated from another loudspeaker located either over the child's head or at 180^0 (directly behind the child). Whenever possible NU6 word lists were employed; however, some young children and children with minimal English were tested using the PBK-50 (Haskins, 1949) or NU-CHIPS (Elliott & Katz, 1980) word tests. The vocabulary used in the latter tests is simpler because the words have been selected to be age-appropriate for younger children[2].

FM-aided soundfield measures were obtained with the volume control of the FM unit set at the user's comfort level. The microphone for the FM system was placed at a calibrated spot in front of the loudspeaker from which the signal emanated. To locate the calibrated spot, the following steps were followed: 1. a 1-kHz warbled pure tone was presented through the loudspeaker with the audiometer set at a dial reading of 65 dBHL; 2. a measurement was taken with a sound-level meter at the position of the child's head; 3. the sound level was measured at positions closer and closer to the loudspeaker until a 20 dB increase over the level measured at the position of the child's head was achieved. By placing the microphone of the FM unit at this spot, it would pick up the signal at a level 20 dB higher than the level arriving at the child's ear, thereby approximating the FM advantage when the lapel microphone is placed within 6 to 8 inches of a talker's mouth (Maddell, 1992).

FM-aided soundfield SRTs were measured in noise using the same procedures that were used in the unaided condition described above, except that the child wore the FM unit (the microphone was placed at the calibrated spot). FM-aided speech discrimination scores were obtained with the speech and competing babble both set to 65 dBHL on the dial of the audiometer (for one child, due to tester error, speech discrimination was not tested in the aided condition). Since the FM microphone was placed nearer to the loudspeaker delivering the speech and farther from the loudspeaker delivering the competing babble, the input to the microphone was at least +20 dB S:N.

Pre-trial Subjective Ratings by Teachers. Prior to the trial with the FM units, the classroom performance of each child was rated by his or her regular classroom teacher using the Screening Instrument For Targeting Educational Risk (SIFTER; Anderson, 1989). The purpose of the SIFTER is to provide a valid method by which children with hearing problems (either known or suspected) can be educationally screened. The SIFTER has been demonstrated to have good content validity for this purpose based on information from the literature, initial teacher review, and two years of teacher evaluation of content areas and question items; based on an evaluation of over 500 students with hearing loss, it was also found to have moderate content reliability (Anderson, 1989). Our interest in administering the SIFTER was to determine if it could be used to predict whether or not a child would benefit from an FM system with headset and to guide initial recommendations regarding equipment use.

The SIFTER (Anderson, 1989) is a 15-item questionnaire which provides a performance rating for five content areas (academic, attention, communication, participation, behaviour). The teacher rates the child's performance against classroom peers for each item using a five-point scale. The total score for each content area, based on three questions per area, is categorized as "pass", "marginal", or "fail". Anderson recommends that children be evaluated by an educational audiologist if they fail in the attention and/or class participation content area in combination with failures on any of the other content areas. She suggests that children falling into the "marginal" area are at risk and should be monitored or assessed depending on additional information.

Post-trial Subjective Ratings by Teachers. An evaluation was carried out immediately following the conclusion of the FM classroom trial using a fifteen-item FM Evaluation Questionnaire that was completed by the classroom teacher. The questionnaire was designed in-house for the project. The questions were formulated by eight audiologists based on clinical experience discussing with teachers how FM systems were used by children in classrooms and using similar existing questionnaires (e.g. the MARRS Project Questionnaire, Sarff, 1981). The FM Evaluation Questionnaire was used to determine whether or not teachers noticed any change in performance that might be attributable to use of the FM system with headset. Teachers were asked for a numerical rating from 1 to 5 (none to very) on eleven items, indicating degree of change in classroom behaviour and academic performance (Appendix A). Qualitative comments on the reactions of fellow students, the child's own reactions, problems understanding or operating the equipment, and general impressions were also gathered.

3. ANALYSIS

Prior to implementing the study, the investigators arrived at a consensus that, in their professional judgement, an average rating of 3.0 ("some improvement") or greater on the FM

Evaluation Questionnaire would be considered to be a clinically or educationally significant indication of benefit (see Green & Kreuter, 1991 for a discussion of standards of acceptability in program evaluation, p. 218). The children who achieved an average rating of 3.0 were considered to have benefited enough from the device that a recommendation for continued use would be warranted.

We also considered how well the pre-trial measures might serve us in trying to predict which children would benefit from long-term use of an FM system. We decided that we would take an improvement of 10 dB or more on the SRT in noise measure, or an improvement of 20% or more on the speech discrimination measure, as evidence that a child was deriving enough signal enhancement from the device in the conditions tested in the soundbooth that it was reasonable to hope for improvements if the device were worn in a classroom situation. According to Berg (1993), even in a relatively good classroom with ambient noise at a level of 55 dBA, it would still be advisable to have a 5 to 15 dB enhancement of signal-to-noise ratio; a 10 dB improvement would fall midway in this range. Differences between speech discrimination scores may be significant if they reach between 4 and 30%, depending on factors such as the number of words in the list and the baseline score (Skinner, 1988, p. 296). Given these guidelines, for our materials and subjects, a difference in speech discrimination scores in quiet was not considered to be significant until it reached 20%. Measures that would help in predicting benefit could be incorporated into any new protocols that might be recommended to the Ministry of Education.

4. RESULTS

4.1 Post-trial FM Evaluation Questionnaire

FM Evaluation Questionnaires were completed for 18 children. One child refused to complete the trial. The teacher of another student did not feel that there had been enough opportunity to observe the child's performance with the FM system although she commented that she felt the child would benefit and that the trial should be continued. Fourteen (78%) of the 18 children who were evaluated achieved an overall rating of 3.0 ("some improvement") or greater on the questionnaire. The overall mean total score for the eleven items rated on the five-point scale was 3.5 (SD = $\pm$ 0.7), with the mean score on all but one of the items being at least 3.0 (Table 2).

There were an additional four questions asking for the teachers' and students' qualitative comments about their impressions and experiences with the FM system. For example, for all but one of the children, a comment was provided in response to Item 12, relating to the reaction of fellow students to the device, and only one of the 18 comments suggested a negative reaction. A typical comment was "Students were all quite impressed and C seemed to like being a bit of a celebrity (he's normally quite shy)."

Item 13, which concerned the child's own reaction to using the unit, also evoked favourable comments from 16 of 18 respondents. Two children, although finding some benefit in using the devices, felt that they would not want to use a device on a full-time basis. Both children were identified as "gifted" and were doing very well in school despite their hearing problems.

Of the 17 teachers who responded to Item 14, none found the equipment difficult to understand or operate, although there were some complaints about the physical quality of the lightweight headsets. Three teachers complained that the headsets were of questionable quality, broke easily, and were a poor fit on small heads.

Of the 17 teachers reporting general impressions in response to Item 15, 15 were strongly in favour of the use of FM systems in the classroom, and the two who taught the "gifted" children were supportive but found it difficult to evaluate the contribution of the device because the children were already at the "top of their class". Comments like the following were common "E.... loved the unit. She became a lot happier and animated in class. She smiled a lot when I was talking just to her. I hope she has access to the unit next year. It was a very rewarding experience for both of us."

4.2 Pre-trial Soundbooth Clinical Measures

SRT in Noise. The mean SRT in noise in the aided condition was 34.7 dBHL (SD = $\pm$ 7.7 dBHL); for the unaided condition it was 48.2 dBHL (SD = $\pm$ 7.9 dBHL). Thus, the average improvement was 13.5 dB. Fourteen (70%) of the children showed improvements of at least 10 dB (Table 3). Furthermore, the improvement in group performance was shown to be significant by a t-test for matched pairs [$t(18) = -7.06$, $p < .001$].

Of the 14 children who showed an improvement of at least 10 dB on the SRT in noise measure, 11 achieved a rating of at least 3.0 on the FM Evaluation Questionnaire, two others were not rated, and one achieved a rating less than 3.0. The one who showed an improvement of at least 10 dB on the SRT in noise measure, but who achieved a rating less than 3.0 on the FM Evaluation Questionnaire, was a child with learning disabilities. There were also three children who achieved a rating of at least 3.0 on the FM Evaluation Questionnaire who did not show an improvement of at least 10 dB on the SRT in noise measure; two of these three were very young children who did not speak English as their native language.

Speech Discrimination in Noise. The mean score for speech discrimination measured in the aided condition (equivalent to +20 dB S:N) was 92.3% (SD = $\pm$ 7.8%). The mean score for speech discrimination measured in the two unaided conditions was 89.8% (SD = $\pm$ 11.2%) in the +10 dB S:N condition, and 81.8% (SD = $\pm$ 13.5%) in the 0 dB S:N condition (Table 3). The difference between the mean scores obtained in the aided condition and in the two unaided

Table 2. Mean improvement in children's' performance as rated by teachers on the post-trial FM Evaluation Questionna

Question	Rating (mean ± SD)	Number of respondents
1	3.8 ± 0.8	18
2	3.6 ± 0.8	18
3	3.7 ± 1.2	18
4	3.2 ± 0.9	17
5	3.3 ± 0.9	10
6	3.2 ± 0.6	17
7	3.2 ± 1.2	17
8	4.2 ± 0.9	18
9	3.0 ± 1.0	12
10	3.2 ± 1.0	18
11	2.9 ± 1.5	15
Total	3.5 ± 0.6	18

Table 3. Comparison of pre- and post-trial measures for individual children

Child	FM evaluation Overall rating	SIFTER Recommendation	Unaided-aided differences in soundbooth measures: SRT in noise (dB)	Speech discrimination score (%)
1	3.4*	monitor	18*	24*
2	4.2*	monitor	11*	7
3	4.2*	intervention	10*	5
4	3.8*	not rated	17*	16
5	3.2*	intervention	20*	-8
6	3.3*	monitor	8	8
7	3.7*	intervention	3	20*
8	2.6	no intervention	5	4
9	3.3*	monitor	16*	0
10	3.6*	intervention	2	4
11	4.0*	intervention	22*	24*
12	3.1*	intervention	15*	25*
13	2.5	no intervention	4	-4
14	4.0*	no intervention	12*	20*
15	2.8	intervention	0	0
16	not rated	no intervention	10*	12
17	2.3	intervention	19*	18
18	4.4*	monitor	11*	8
19	did not complete trial	intervention	28*	not tested
20	4.8*	monitor	30*	20*

* Children who demonstrated a clinically significant difference.

conditions were 2.9% and 10.5% respectively. Only when aided performance was compared to performance in the 0 dB S:N condition was improvement shown to be significant by a t-test for matched pairs [$t(18) = 4.32$, $p < .001$].

Six children (32%) showed improvements of 20% or greater when the aided speech discrimination score was compared to unaided performance in the noisiest condition. Of these six, all achieved a rating of at least 3.0 on the FM Evaluation Questionnaire. Five of the six also showed an improvement of at least 10 dB on the SRT in noise measure, and the one who did not was learning English as a second language. There were, however, eight children who achieved a rating of at least 3.0 on the FM Evaluation Questionnaire who did not show an improvement of at least 20% on speech discrimination in noise; there does not appear to be any particular subject characteristic common to these children.

4.3 Pre-trial Subjective Ratings by Teachers

The SIFTER was completed for 19 of the 20 children in the study. One child with Down Syndrome was not rated because the teacher felt that the child's level of function in the classroom was too low for it to be appropriate to make a comparison between this child and other children in the class[3]. The number of children who fell into the "fail" or "marginal" categories prior to the trial with the FM system were as follows: 11 (58%) in the academic area; 14 (74%) in the attention area; 14 (74%) in the communication area; 9 (47%) in the participation area; 10 (53%) in the behaviour area. Following Anderson's (1989) recommendations, follow-up by an educational audiologist was indicated for eight (42%) of the children, monitoring was indicated for an additional seven (37%), and no further intervention was

Table 4. SIFTER ratings by teacher of child's classroom performance

Child	Content Area				
	Academic	Attention	Communication	Participation	Behaviour
1	Pass	Marginal	Marginal	Pass	Marginal
2	Fail	Marginal	Marginal	Marginal	Marginal
3	Fail	Fail	Pass	Marginal	Fail
4	Not Rated				
5	Fail	Fail	Fail	Fail	Fail
6	Pass	Marginal	Marginal	Pass	Pass
7	Fail	Marginal	Fail	Pass	Pass
8	Pass	Pass	Pass	Pass	Pass
9	Pass	Pass	Marginal	Pass	Pass
10	Pass	Marginal	Fail	Pass	Fail
11	Fail	Fail	Fail	Fail	Fail
12	Fail	Fail	Fail	Marginal	Fail
13	Pass	Pass	Pass	Pass	Pass
14	Marginal	Pass	Pass	Pass	Pass
15	Marginal	Marginal	Fail	Fail	Marginal
16	Pass	Pass	Pass	Pass	Pass
17	Fail	Fail	Fail	Fail	Fail
18	Marginal	Marginal	Marginal	Marginal	Pass
19	Marginal	Fail	Marginal	Pass	Marginal
20	Pass	Marginal	Marginal	Marginal	Pass

indicated for the other four children (21%). Individual profiles on the SIFTER can be seen in Table 4.

Of the 14 children who received an overall rating of at least 3.0 on the FM Evaluation Questionnaire, following Anderson's (1989) recommendations, six would have received intervention, six would have been monitored, one would have received no intervention, and one child who had Down Syndrome would not have been rated. Of the four children who did not satisfy the criterion for success on the FM Evaluation Questionnaire, according to Anderson's (1989) recommendations, two should have received intervention, and two should have received none.

5. DISCUSSION

Our first objective was to determine if the children who participated in the study would benefit from wearing an FM system in the classroom. Benefit, as measured subjectively using the teacher's rating of improvement in classroom performance over the trial period, was demonstrated by the majority (78%), but not all, of the children who participated in the study. Furthermore, on pre-trial, objective, audiologic measures, 14 children (70%) showed at least a 10 dB improvement in SRT in noise, and six children (32%) showed improvements of at least 20% in speech discrimination scores in noise when the FM system with headset was worn.

These results provide evidence that the majority of students with minimal-to-mild, fluctuating conductive, or unilateral hearing loss can be expected to benefit from wearing an FM system with headset in the classroom. Although conventional hearing aids or traditional FM systems were not indicated for these cases according to existing provincial ministry guidelines, the potential usefulness of an assistive listening device such as an FM system with headset is supported by both subjective and objective measures of performance.

Our second objective was to determine if pre-trial audiometric measures or teacher ratings could be used to distinguish between children who would or would not be likely to benefit from wearing an FM system with headset.

Of the 14 children who were rated post-trial and who did receive an overall rating of at least 3.0 on the FM Evaluation Questionnaire, 11 showed an improvement of at least 10 dB on the SRT in noise measure and six showed an improvement of at least 20% on the speech discrimination test. Of the four children who were rated post-trial and who did *not* receive an overall rating of at least 3.0 on the FM Evaluation Questionnaire, only one (the child with learning disabilities) showed an improvement of at least 10 dB on the SRT in noise measure, and none showed an improvement of at least 20% on the speech discrimination in noise test.

Of the audiometric measures, SRT in noise seems to be more useful than speech discrimination for identifying those who will benefit from an FM system with headset. Had a criterion of a 10 dB improvement in SRT in noise been adopted to determine which children would receive a trial with the FM system with headset, 14 would have been correctly categorized: 11 children who benefited would have been fit, and three (# 8, # 13, # 15) who did not benefit would not have been fit. However, four children would have been incorrectly categorized: one child (with learning disabilities, # 17) would have been fit who did not benefit, and, of greater concern, three children who did benefit would not have been fit. Of the three who would not have been fit, two (# 6 and # 7) were young children who did not speak English as a native language. There is no obvious explanation for why the other child (# 10) did not show an improvement on SRT in noise even though the teacher felt that the child had shown improvement in classroom performance. Perhaps the teacher of this child was influenced by expectations regarding the usefulness of the equipment. Overall, we concluded that pre-trial measures of SRT in noise could be used to identify most children who would benefit from wearing an FM system; however, audiometric measures based on speech perception should not be used to decide against a trial with an FM system with headset for very young children who are learning English as a second language. Such audiometric measures may also not be sufficient to ensure benefit in the case of children, such as the child with a learning disability, who have conditions other than hearing loss that affect their classroom performance.

It is noteworthy that most of the children had pre-trial classroom difficulties, as reported by the teachers on the SIFTER, in one or more areas (academic, attention, communication, participation, behaviour). The pre-trial classroom profiles that were reported by the teachers would have triggered intervention for nine children (47%), monitoring for six (32%), but no intervention for four (21%).

Had we used the SIFTER to decide which children would receive a trial with an FM system with headset, adopting a decision rule to fit all of the students for whom Anderson (1989) would recommend intervention *or* monitoring, then 15 would have been correctly categorized and three would have been incorrectly categorized. Using this decision rule, 13 of the 14 children who benefited from wearing the FM system with headset would have received a trial, but devices would also have been fitted on two children who did not benefit from them. In one of these cases (# 15), the child did not meet the criteria for change in SRT in noise; and the other case (# 17) was the child who likely did not benefit from the FM system because of a learning disability. Only one child who benefited would not have been given a trial (# 14). Note that this child would have been fitted with an FM system with headset if we had based our decision on change in SRT in noise. In addition, we would have correctly decided *not* to try the FM system with headset on two children (# 8 and # 13) whose teachers rated them as not benefiting from the device, both of whom were considered by the teachers to be "gifted" students and both of whom showed less than a 10 dB improvement on SRT in noise.

Overall, decisions based on the SIFTER and the SRT in noise measure were both helpful but not perfect for determining who would or would not be likely to benefit from the use of an FM system with headset. The objective SRT in noise measure and the subjective SIFTER measure had similar test sensitivity and specificity. Decisions based on the SIFTER would have resulted in slightly more devices being fit, including more on those who showed post-trial benefit and those who did not. In contrast, decision based on the SRT in noise are would have been more conservative and resulted in fewer devices being fit, both on those who showed no post-trial benefit and those who did. Those *not* likely to benefit from an FM system with headset because they are already excellent students, would have been correctly identified on the basis of either measure. It could be argued that such students may indeed benefit from an FM system, but that it is difficult to assess their benefit using either teacher ratings or audiometric measures because they are performing so well unaided. The only subject who did not benefit from the FM system with headset, and who would not have been identified as a poor candidate by the subjective or objective measures, was a child with a learning disability; neither measure was useful in predicting if benefit would be achieved by this child. It is possible that it is difficult to appreciate benefit in a case like this one because the child is performing at floor due to other problems that are unsolved by assistive listening devices. Not surprisingly, because the SRT in noise measure uses speech materials, it was not as helpful as the SIFTER in predicting benefit from the device for very young children who were learning English as a second language. In contrast, other children with special needs, such as the children with Down Syndrome, and older children learning English as a second language, did benefit from the FM system with headset and there was agreement between audiometric and teacher ratings for these cases.

It is interesting that there was a lack of any significant correlation between the objective or subjective pre-trial measures and the post-trial measures, indicating that the assessment instruments used in this study with these participants were not predictive of degree of benefit. Subjects who showed good benefit in the soundbooth did not always receive proportionately high ratings for improved performance in the classroom. Conversely, while good performance in the soundbooth did not guarantee success with the device, relatively good performance on the SIFTER did not prohibit success. For example, teachers judged that performance improved significantly for all subjects who performed well enough on the SIFTER to be recommended for monitoring rather than intervention. Clearly, individual differences in the personalities of the children, their academic performance, their exceptionalities, and the specific classroom settings all played a role in the outcomes of the trials. The impact of these factors could not be precisely predicted by the SIFTER or soundbooth evaluations and only became apparent during the actual trial in some cases. Especially in the cases of the exceptional children, a trial period would clearly be needed in addition to pre-trial measures. Although the sample size studied is small, the results highlight the importance of taking all factors into consideration when audiologists and teachers contemplate the fitting of an FM system.

It seems that FM systems with headsets can provide effective assistance in the classroom for many children who suffer from lesser degrees of hearing loss and for whom conventional amplification is inappropriate and preferential seating insufficient. Based on our findings, we recommended that FM systems with lightweight headsets be included as an option in the Auditory Training Equipment Program of the British Columbia Ministry of Education. Nevertheless, the recommendations were not implemented largely due to lack of available funding for the equipment.

Finally, because almost all of the children with these lesser degrees of hearing loss seem to benefit from the enhancement of signal-to-noise ratio provided by the equipment, we wonder if we would find that children with normal hearing would also benefit. Since classrooms are often acoustically hostile, and because spoken communication is so integral to classroom education, it seems important to consider that, for the long-term, it might be more cost-effective to improve classroom acoustics, or at least to build new classrooms with superior acoustical characteristics, than to purchase and maintain equipment for a large number of children who would not need assistance in more favourable listening conditions. In order to determine the best long-term solution, it would be necessary to conduct a cost-benefit analysis of the alternatives.

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7. FOOTNOTES

1. One child refused to complete a trial following assessment. A three-week strike by the teachers in one school district caused a disruption in the trials for approximately half of the children; however, all children did use the equipment for at least two months.
2. While the use of different tests would be unacceptable in tightly controlled experimental conditions, our purpose was to determine if the best available clinical measures could be used to determine benefit from the FM systems with headset. For each child, the same test was used in both aided and unaided conditions.
3. Teachers were comfortable rating all of the other children as required by the SIFTER.

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APPENDIX A

FM Evaluation

Student: ____________________ Date: ______________________
Equipment: __________________ Class Size: ________________
Teacher: ____________________ School: ____________________

Item	Question	None 1	2	Some 3	4	Very 5
1.	Helpful in improving student attention (i.e. listening to instructions)					
2.	Helpful in improving on task behaviour (i.e. following instructions)					
3.	Helpful in improving concentration of student during oral presentations					
4.	Helpful in improving class participation					
5.	Helpful in improving student test performance and achievement					
6.	Helpful in increasing the pace of instruction (i.e. less re-instruction)					
7.	Helpful in improving student attitude					
8.	Helpful in reducing teacher voice fatigue					
9.	Helpful in overcoming problem of interfering classroom noise					
10.	Helpful in classroom management (i.e. fewer problem behaviours)					
11.	Have you noticed any change in the student's attitude? (i.e. enthusiasm for school)					

12. Reactions of fellow students:
13. Student's own input:
14. Any problems understanding or working equipment?
15. Comments/General impressions: