

The Benefits of Sound Field Amplification in Classrooms of Inuit Students of Nunavik: A Pilot Project

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Consistent auditory input and an optimal listening environment are essential to the development of the cognitive, linguistic, academic, and social skills that are associated with achievement in school. Competence in these skills provides access to learning in instructional interactions. The audibility and intelligibility of the speech signal are particularly crucial when skills in either the first or second language are being acquired. Because the majority of the teaching that takes place in classrooms revolves around oral instruction and interaction, the ability to detect, attend to, and understand the teacher's words are essential prerequisite skills for learning in the school setting (Bashir, Conte, & Heerde, 1998; Cazden, 1988; Flexer, Millin, & Brown, 1990; Nelson, 1985; Wallach & Miller, 1988).

The acoustic and auditory conditions of the classroom typically result in difficult listening conditions that can have a significant negative impact on learning. Acoustic variables that have been found to produce negative effects on the classroom listening environment include reverberation time, the distance from the teacher to the student, and the level of the teacher's voice in relation to the background noise that is present in the classroom (Berg, 1993; Crandell, Smaldino, & Flexer, 1995; Finitzo, 1988; Flexer, 1995; Palmer, 1997). Normal hearing levels alone do not, therefore, guarantee optimal audibility and intelligibility of the speech signal in classrooms.

The sound field FM system is a form of amplification technology that has proven to be very effective in improving listening conditions in classrooms. A typical classroom

ABSTRACT

Purpose: This pilot study investigated the potential benefits of sound field amplification for Inuit first and second language learners in a remote community of Nunavik, Northern Québec. Hearing screening results showed that 26% of students attending the local school had hearing loss due to otitis media. The study used speech intelligibility and attending behavior measures, as well as interviews, to examine the appropriateness of sound field amplification in the multilingual and multilevel instructional contexts found in the classrooms of Nunavik.

Method: Sound field amplification systems were installed in three representative classrooms for a period of 3 months. Speech intelligibility of Inuit syllables was compared in amplified versus non-amplified conditions for 10 students with hearing loss and 10 age-matched normal hearing peers. Observations of four categories of attending behaviors for a separate set of seven students were carried out prior to the

installation of the systems and with the systems in place. Teacher and student comments were collected during the study and after the study was completed.

Results: Results showed significant improvements in speech intelligibility scores for students with hearing impairment and normal hearing in the amplified condition. Total scores for on-task behavior improved for six of the seven students observed; all students demonstrated improvement in at least one category of attending behavior. Teacher and student comments identified numerous advantages of the amplification systems.

Implications: Results point to the potential benefits of sound field amplification for multicultural populations that are similarly challenged by high rates of hearing loss, as well as for second language learners.

KEY WORDS: sound field amplification, classrooms, Inuit, otitis media

amplification system is composed of a wireless microphone/transmitter worn by the teacher, an amplifier, and two to four loudspeakers that can be mounted either on the walls or the ceiling of the class. When using the sound field system, the teacher's voice is slightly amplified; background noise is not. The improved signal-to-noise ratio (SNR) results in a feeling of "surround sound" for learners, making the teacher's voice much easier to understand from any location in the classroom (Berg, 1993; Crandell et al., 1995; Flexer, 1995).

Results of numerous studies that have been carried out in mainstream classrooms demonstrate significant positive effects of sound field FM use on word and sentence recognition, spelling, reading, and overall academic achievement for students with and without hearing loss (Allen & Patton, 1990; Blair, Myrup, & Viehweg, 1989; Crandell & Bess, 1987; Flexer, 1992; Neuss, Blair, & Viehweg, 1991; Palmer, 1998; Zabel & Tabor, 1993). In particular, a 3-year study conducted by Ray (1992) compared the academic performance of students with mild hearing loss placed either in sound field amplified classrooms or in unamplified classrooms supplemented by resource instruction. Results showed significantly greater academic gains among students in the amplified classrooms, particularly in the areas of reading and language arts.

Sound field FM systems have also been shown to have a positive impact on classroom behavior and attentiveness. Students with and without hearing loss have demonstrated increased on-task behavior and have been found to be less distractible and more attentive in sound field amplified classrooms (Allen & Patton, 1990; Gilman & Danzer, 1989; Palmer, 1998). Classroom amplification systems have been used successfully in classrooms of students with learning disabilities, attention deficit disorder, and developmental delays, as well as with students learning a second language (Blake, Field, Foster, Platt, & Wertz, 1991; Crandell, 1996; Flexer et al., 1990; Ray, Sarff, & Glassford, 1984). Positive benefits of sound field amplification for teachers include less frequent teacher absences from school and teacher reports of decreased vocal strain and fatigue (Crandell et al., 1995; Flexer, 1989; Gilman & Danzer, 1989).

The present study describes a 3-month pilot project investigating the potential benefits of sound field amplification in classrooms of Inuit and non-Inuit teachers. The study was carried out between January and April 1997 in Kangiqsualujjuaq, a village of approximately 650 Inuit on the coast of Ungava Bay in the Nunavik region of Northern Québec. The project had three goals:

1. Document whether sound field FM systems might improve speech intelligibility as measured using Inuttitut syllables for students with normal hearing and students with hearing impairment.
2. Determine whether measurable improvements in attending behaviors for students with hearing loss and learning difficulties might be documented as a result of sound field amplification.
3. Examine whether the educational circumstances typical of Nunavik classrooms might affect the acceptance and the usefulness of the systems.

THE GEOGRAPHIC, DEMOGRAPHIC, AND SOCIOCULTURAL CONTEXT OF NUNAVIK

Nunavik, the Inuit name for the territory of Northern Québec that lies north of the 55th parallel, covers approximately one-third of the province's total land mass. The majority of this territory lies above the tree line where the climate is harsh and vegetation is sparse. The Inuit population of Nunavik numbers approximately 8,000 and is distributed across 14 remote communities located along the coasts of Hudson Bay and Ungava Bay. These communities vary in size from approximately 150 to 1,500 persons and are accessible to each other and to the south only by air.

The Inuit of Nunavik continue to rely on traditional subsistence activities in addition to cash wage employment. The primary language of communication in Nunavik is Inuttitut. Inuit students are educated in Inuttitut by Inuit teachers from kindergarten through Grade 2, in some cases through a team-teaching approach with an Inuit teacher assistant. According to the language policy of the Kativik School Board, the transition between Inuttitut and second language instruction in either English or French takes place at the Grade 3 level. The upper grades are typically taught by non-Inuit teachers; however, students continue to have several classes a week in Inuttitut, including religion, Inuit culture, and Inuttitut language instruction. Because of the small number of students, many classes in the smaller Inuit communities are made up of multilevel groupings that may include from two to four grades in a single classroom. Students at the secondary level may have different teachers for different subject areas.

INSTRUCTIONAL DISCOURSE IN CLASSROOMS OF INUIT TEACHERS

Instructional discourse and interaction patterns in classrooms of Inuit teachers have been found to be organized in ways that differ substantially from mainstream educational interactions (Eriks-Brophy, 1992, 1997; Eriks-Brophy & Crago, 1994). The initiation-response-evaluation sequences that characterize many mainstream classroom interactions (Cazden, 1988; Mehan, 1979) were not found to predominate in Inuit classrooms. Instead, Inuit teachers tended to engage in interactional sequences that focused on appropriate group participation. Elicitations for information were typically directed to the class as a whole and only rarely were individual students selected to respond to teacher-initiated questions. Evaluation of student responses was also directed toward the group as a whole rather than toward individual students. Overall classroom talk was relatively equally shared between teachers and students, and students were able to interject comments and questions relatively freely within lessons. Inuit teachers encouraged and promoted student interaction, both verbal and nonverbal, which resulted in more peer talk and physical contact among students than is typical of mainstream classrooms.

The forms of discourse and interaction that were observed in Inuit classrooms were described by the Inuit teachers who participated in the studies as representing culturally appropriate ways of teaching children, with the goal to promote the equality of all group members in the classroom. These teachers described the role of the teacher in the Inuit classroom as serving primarily as a facilitator of student talk and interaction, rather than as an authority, and as an orchestrator of instructional exchanges. Although the communities of Nunavik are experiencing rapid growth and change, the importance of listening to and respecting others and the development of appropriate and responsible behavior as a member of the group continue to be important cultural values in present-day Inuit society (Crago, Annahatak, & Ninguiruvik, 1993; Eriks-Brophy, 1997).

THE PREVALENCE OF OTITIS MEDIA IN NUNAVIK

Another important consideration in this study was the high prevalence of otitis media (OM) in the Inuit children of Nunavik. In a recent survey of the epidemiology of chronic OM, Bluestone (1998) reported that the highest rates of chronic OM in the world (12% to 46%) were found in the Inuit populations of Canada, Alaska, and Greenland. A study carried out in one Nunavik community found that 78% of Inuit schoolchildren had current or previous ear infections, and that 23% of these children had a significant hearing loss in one or both ears at the time of the hearing screening (Julien, Baxter, Crago, Ilecki, & Therien, 1987).

Since 1985, Inuit from Nunavik have received specialized audiological services through the Hearing and Otitis Program, which is composed of a travelling team of specialists including an audiologist, an Inuit audiologic assistant, and a hearing aid specialist. Trained Inuit personnel constitute an integral part of this program (Crago, Hurteau, & Ayukawa, 1990). Inuit schoolchildren are screened for hearing problems and middle ear disease by local community health workers and Inuit audiological assistants. Otoscopy is performed and a threshold search is carried out at .5, 1, 2, and 4 kHz using a portable audiometer in a quiet room. Those children failing the screening are seen on the annual hearing and otitis team visit.

The most common cause of hearing loss among Inuit children is chronic OM or chronic suppurative otitis media, a condition where the tympanic membrane(s) are perforated and may or may not be draining fluid. The associated hearing loss may fluctuate from day to day, and, if the tympanic membrane heals, hearing levels sometimes return to normal. Some students have fluctuating hearing loss due to middle ear effusion.

Many Inuit children who have been identified with hearing loss have been fitted with hearing aids; however, maintaining consistent hearing aid use has proven to be problematic. Behind-the-ear hearing aids cannot be worn when the ear is draining. Older students may refuse to wear bone-conduction aids, stating that the conspicuousness of

this type of hearing aid singles them out from their peers. Broken hearing aids take time to replace given Nunavik's isolated location. Consequently, many students with hearing loss are not receiving consistent amplification in the classroom setting and are at risk for educational difficulties as a result of their reduced hearing levels (Zinkus, 1986).

The present study investigated the usefulness of sound field amplification in this exceptional educational context. It was hypothesized that there could be substantial benefits in these classrooms because of the second language instructional contexts and the high prevalence of hearing loss. However, it was not known whether sound field amplification would be accepted by Inuit students and Inuit teachers, or whether sound field systems could be used appropriately in the multilevel, team-teaching, and second language educational contexts that are typically found in the isolated communities of northern Québec. The study attempted to document the effectiveness of sound field amplification systems in two ways: (a) assessing changes in performance on speech intelligibility measures and student attending behaviors, and (b) soliciting teachers' and students' comments regarding sound field amplification.

METHODS

Participating Classrooms and Procedures

Hearing and otitis files were reviewed from the previous academic year to determine the prevalence of hearing loss in all of the classes in the school. A review of the files found that 50 of 194 students, or 26% of the school population, had either unilateral or bilateral hearing loss. Normal hearing was defined as a hearing level of 20 dBHL or better at 1, 2, and 4 kHz, and 25 dBHL or better at .5 kHz in both ears. Hearing loss was more frequent in the younger than in the older students. Results of the hearing screening are provided in Table 1.

Three classrooms were then chosen to participate in the study on the basis of the prevalence of hearing loss, teacher interest, and also in order to capture the unique instructional contexts of Nunavik schools, as previously described. An Inuit school board representative presented the pilot project to the community through the local radio station, and the project was subsequently approved by the local education committee. Parental consent for participation was obtained for all students enrolled in the target classrooms. A total of 20 students was selected for participation in the speech intelligibility test, and seven students participated in the behavioral observation study. The target classrooms included the following:

- A Grade 2 Inuit classroom of 19 students, aged 7–8 years, involving a team-teaching situation with an Inuit teacher and an Inuit teacher's aid. This class was selected in order to document whether sound field amplification might be incorporated effectively into a classroom where Inuit instructional practices and a team-teaching approach were being used. Forty-two percent of the students in this classroom had some

Table 1. Hearing test results by classroom.

| Class | Total # of students | Students with hearing loss | Percentage of students with hearing loss |
|--------------------------------|---------------------|----------------------------|--|
| Kindergarten A | 12 | 4 | 33 |
| Kindergarten B | 13 | 3 | 23 |
| Grade 1A Inuttitut | 8 | 0 | 0 |
| Grade 1B Inuttitut | 9 | 3 | 33 |
| Grade 2 Inuttitut ^a | 19 | 8 | 42 |
| Grade 3 French | 13 | 3 | 23 |
| Grade 3 English ^a | 19 | 5 | 26 |
| Grade 4, 5 French | 19 | 6 | 32 |
| Grade 4, 5 English | 16 | 4 | 25 |
| Grade 6, 7 French | 9 | 1 | 11 |
| Grade 6, 7 English | 15 | 4 | 27 |
| Sec. 1, 2 French ^a | 9 | 1 | 11 |
| Sec. 1 English | 13 | 1 | 8 |
| Sec. 2, 4, 5 English | 10 | 2 | 20 |
| Special Needs Class | 10 | 5 | 50 |
| Total | 194 | 50 | 26 |

Note. Sec. = secondary.

^a Classroom chosen to participate in the study.

degree of hearing loss, including four students who wore hearing aids.

- A Grade 3 English classroom of 19 students between 8–9 years of age to document the effects of the system during the students' first year of exposure to second language instruction. In this class, 26% of the students had hearing loss, with four students using hearing aids.
- A secondary classroom to observe how the system would be accepted by adolescent Inuit students, aged 13–17 years, and how effective the systems might be for multilevel groupings. This secondary 1 and 2 class (equivalent to grade 7 and 8 in the United States) of 9 students was taught in French by two teachers who each taught different subjects. One student had a hearing loss and used a hearing aid.

Measures

Sound field FM installation. Easy Listener sound field FM systems provided by the Phonic Ear Corporation were installed in the three target classrooms according to specifications. Upon installation, the FM system amplifier was adjusted to the mid-position for tone and volume. Output was routed to four loudspeakers, one mounted on each wall. Because the classrooms differed in dimension, slightly different levels of gain were to be expected in each classroom.

Participating teachers were provided with in-service training on the use of the systems at the time of installation, and regular contact with the participating teachers was maintained by telephone and fax throughout the trial period. Students in the target classrooms were encouraged to continue to use their personal hearing aids during the trial

period in order to be able to hear other students' questions and comments. The majority of students with hearing aids did continue to use them. Teachers were encouraged to pass the microphone to students who were reading aloud or making oral presentations. This technique both encouraged the students to use the technology and allowed the other students to hear comments made by their peers. The systems were left in place for a period of 3 months.

Sound level measurements. An Aclan SIP95 sound level meter was used to measure the teacher's voice, background noise levels, and sound field gain in each of the classrooms. An average measure (dBA) was taken for 1 minute. Classroom noise levels were measured in mid-classroom with the fluorescent lighting on and the door and windows closed. Gain in unoccupied classrooms was calculated as the difference between amplified and unamplified levels of white noise. In occupied classrooms, gain was measured as the difference between amplified and unamplified teacher voice levels at a distance of 8–10 feet.

Speech intelligibility measures. Ten students with bilateral hearing loss and 10 age-matched students with normal hearing participated in the speech intelligibility portion of the study. Because of the fluctuating nature of their hearing loss, these students were all retested within 1 week of participating in the speech intelligibility measures. Students with hearing loss had a pure tone average (PTA) at .5, 1, 2, and 4 kHz of 25 dBHL or poorer in both ears. The mean PTA was 34.8 dBHL in the left ear and 37.4 dBHL in the right ear. This group was composed of six boys and four girls ranging in age from 7:11 (years:months) to 11:11. Students in the group with normal hearing sensitivity had a PTA in both ears of 16 dBHL or greater. The mean PTA in both ears was 11.7 dBHL. Speech intelligibility scores were also obtained for the four boys and six girls in this group, who ranged in age from 7:4 to 11:3.

Speech intelligibility of Inuttitut syllables was compared in the amplified and unamplified condition. The speech intelligibility material consisted of taped recordings of two randomized lists of 42 Inuttitut syllables. The recordings were made on a cassette recorder by a native Inuttitut speaker. Inuttitut syllables were used as stimuli in order to avoid any potential confounding effects of second language proficiency on speech perception scores. The tape recorder presenting the test material was placed approximately 12 feet in front of the student. The teacher's sound field FM microphone was placed approximately 4 inches from the speaker of the tape recorder. During the testing, a background noise of 60 dBA cafeteria noise was provided by a tape recorder placed approximately 6 feet behind the subject. The SNR was approximately +3 dB in the amplified condition and -3 dB in the unamplified condition. The FM system thus provided a gain of approximately 6 dB.

This SNR was chosen in order to avoid any potential ceiling effects for the students with normal hearing or floor effects for the students with hearing loss. Each student was tested individually. Students heard one list of syllables with the amplification system on and the other list with the system off, with the order of presentation of the listening conditions alternated between subjects. Students repeated the syllables that were presented on the tape recordings.

Responses were scored as either correct or incorrect by a native Inuttituk speaker.

Behavioral observation measures. Seven students, including one student with a hearing loss and one student with a learning, behavioral, or attentional difficulty, enrolled in the target classrooms were selected in consultation with the classroom teachers to participate in the behavioral observation phase of the study. None of these students participated in the speech intelligibility portion of the study. Three students were selected from the Inuttituk Grade 2 class. Student 1 had a mild bilateral hearing loss, was a hearing aid user, and was experiencing academic difficulties. Student 2 had normal hearing but exhibited behavioral and attentional problems in class. Student 3 was an excellent student and was chosen in order to observe the effect of the system on students without hearing, learning, or behavioral problems. Student 4, from the Grade 3 English class, had a mild hearing loss in the left ear and a moderately severe loss in the right ear. This student was a hearing aid user and had academic difficulties in both first and second language instruction. Student 5, in the Grade 3 class, had learning and attentional difficulties. Students 6 and 7 were from the secondary 1 and 2 French classroom. Student 6 had fluctuating hearing loss due to bilateral perforations as well as attentional and motivational difficulties. Student 7 was having problems in reading and writing in both French and Inuttituk. This student was impulsive, easily distracted, and physically active in class. All of the students were aware that the researchers were present in the school to examine the usefulness of the sound field systems in the classroom; however, students were not informed of the specific measures being used to document sound field effectiveness.

The methodology for the on-line observational measures and the attending behaviors selected for observation were based on a previous study by Blake et al. (1991) using interval sampling techniques. Measurements of attending behaviors were based on on-line observation in the classroom setting by one of the researchers, who had extensive experience observing Inuit teachers and students. Students were observed individually and as unobtrusively as possible for a period of 15 minutes before installation of the system (pre) and for a second 15-minute period after the systems had been in place for 3 months (post). Each 15-minute observation period was broken down into 60 intervals of 15 seconds during which students were observed for 10 seconds, followed by a 5-second interval in which the presence or absence of the attending behaviors was recorded. The student received one point for each attending behavior present.

A total score for each category of behavior and a collapsed score of all four behaviors was calculated for the pre- and post-observation periods. Direct on-line observation was used because it was considered to be less disruptive in the classroom than videotaping. Internal consistency in the scoring of the behavioral observations was maintained by using the same observer for all observation sessions across both time periods. Lessons in which behavioral observations were conducted were kept as similar as possible during the two time periods and across

the three classrooms by selecting the same subject area and participation structure for each observation.

Attending behaviors were selected based on their objective and culturally unbiased definitions and their transparency of observation. The attending behaviors used in the pilot project were (a) student watches the teacher, (b) student's body is oriented toward the teacher or the activity, (c) there is an absence of extraneous body movement, and (d) there is an absence of extraneous talk to peers. These criteria were discussed with an experienced Inuit consultant and were verified as being appropriate for Inuit children prior to their adoption.

- Examples of behaviors that are indicative of not watching the teacher included students engaged in reading materials unrelated to the lesson, daydreaming, drawing or doodling on notebooks or worksheets, gazing out the window or at peers, or playing with objects unrelated to the lesson at hand.
- Examples of excessive movement and lack of body orientation toward the activity included frequent moving or rocking of chairs, desks, or tables; tapping feet or fingers noisily on desks or tables; roving about the classroom; roughhousing with peers; or physically orienting oneself away from the instructional interaction.
- Examples of excessive talk with peers consisted of verbal interactions with other students that were obviously off-topic and often accompanied by physical contact.

In many cases, several behaviors indicative of a lack of attention to the class activity were observed simultaneously. Simultaneously occurring behaviors were scored independently, and the presence of each attending behavior was scored only once for each time interval.

Teacher and student interviews. Teachers participated in formal individual interviews regarding their perceptions of the target students' level of performance in the classroom prior to the installation of the systems. The Screening Instrument for Targeting Educational Risk (SIFTER, Anderson, 1989), a written questionnaire designed to identify educational difficulties due to hearing problems, was used as a basis for conducting the interviews. Additional interview questions were related to the educational background of the students who had been selected to participate in the behavioral observation phase of the project, the reasons for the selection of these students, a profile of the students' strengths and weaknesses, and areas of improvement that teachers would like the students to demonstrate. Teacher responses were recorded directly onto the SIFTER response form and the teacher interview guide.

Both teachers and students were interviewed regarding their overall impressions of the systems at the end of the 3-month trial period. Teachers were again asked to complete the SIFTER for each of the target students and to participate in individual interviews, which were audiotaped and transcribed. The post-interview questions included teacher perceptions of notable areas of improvement in the performance of the participating students as well as the class as a whole, teacher and student ease in adapting to the technology, the average

amount of time the system was used during the day, the durability of the equipment, any problems noted during the trial period, and the appropriateness of the technology for teaching Inuit students. All of the students in the three target classrooms participated in an informal group interview during which they were asked to comment on their reactions to having the system in their classroom, their adaptation to the technology, and the ways in which they found the system helpful to them in learning. Student interviews were conducted in Inuttitut for the two groups of younger students and in French for the older students. Student comments were noted on the interview guide.

RESULTS

Classroom Acoustic Measures

Results of the classroom acoustic measures are presented in Table 2. Unoccupied classroom noise levels ranged from 32.9 to 38.7 dBA. When students were present in the classroom, the noise levels ranged from 57.6 to 61.9 dBA. The least noise was measured in the secondary classroom, which was larger and contained fewer and older students. Without amplification, the SNRs in occupied classrooms ranged from 1.2 to 4.8 dB.

Sound field system gain was measured in the occupied and unoccupied classrooms. As expected, less gain was measurable when students were in the classroom. As shown in Table 3, the SNR in the classrooms improved to between 2.8 and 10.2 dB when sound field amplification was in use.

Table 2. Classroom noise levels and teachers' voice levels in unamplified classrooms.

| Classroom | Unoccupied noise level | Occupied noise level | Teacher's voice level unamplified | SNR unamplified |
|-------------------|------------------------|----------------------|-----------------------------------|-----------------|
| Grade 2 Inuttitut | 35.6 dBA | 61.9 dBA | 63.1 dBA | 1.2 |
| Grade 3 English | 32.9 dBA | 63.5 dBA | 65.6 dBA | 2.1 |
| Sec. 1, 2 French | 38.7 dBA | 57.6 dBA | 62.4 dBA | 4.8 |

Note. SNR = signal-to-noise ratio; sec. = secondary.

Table 3. Gain provided by the sound field amplification systems.

| Classroom | Gain of system: unoccupied classroom | Gain of system: occupied classroom | Teacher's voice level amplified | SNR amplified |
|-------------------|--------------------------------------|------------------------------------|---------------------------------|---------------|
| Grade 2 Inuttitut | 5.8 dB | 1.6 dB | 64.7 dBA | 2.8 |
| Grade 3 English | 11 dB | 2.1 dB | 67.7 dBA | 4.2 |
| Sec. 1, 2 French | 6 dB | 5.4 dB | 67.8 dBA | 10.2 |

Note. SNR = signal-to-noise ratio; sec. = secondary.

Speech Intelligibility Measures

Statistical differences in speech intelligibility scores (the number of errors made for the 42 Inuttitut syllables) were assessed using *t* tests with the Statistical Package for the Social Sciences (SPSS, 1998) statistics package, version 9.0. Parametric statistical tests require data to meet the assumptions of distribution normality and equality of variance. The assumption of normality was tested using the Kolmogorov-Smirnov test for small sample sizes (Sokal & Rohlf, 1969). The assumption of homogeneity of variances was tested using the Levene test for equality of variances within the SPSS procedures. The data met all assumptions. Also, when more than one statistical comparison is performed on the same data set, a risk of increased Type 1 error occurs. Because five comparisons were performed, the Bonferroni correction (Glass & Hopkins, 1984) was applied to control for family-wise error rate. The resulting corrected alpha level per comparison was .01.

For the entire sample of students with and without hearing loss, no significant differences in performance attributable to gender or order effects were observed using a *t* test for independent samples. Results of the speech intelligibility measures for the students with hearing loss are presented in Table 4 and illustrated in Figure 1. Using a paired *t* test, significant mean differences in speech intelligibility scores were observed with the system on versus off ($t(9) = 8.39, p < .01$), with a mean improvement of 16.2 (range 10–28). Performance on the speech intelligibility measures for the students with normal hearing are presented in Table 5 and illustrated in Figure 1. As was the case for the students with hearing loss, a paired *t* test indicated that students with normal hearing showed significant improvements in performance with the amplification system on versus off ($t(9) = 9.39, p < .01$), with a mean improvement of 9.7.

Figure 1. Mean error scores on the speech intelligibility measures for the normal hearing group ($n = 10$) and for the group with hearing loss ($n = 10$) with the amplification system off versus on.

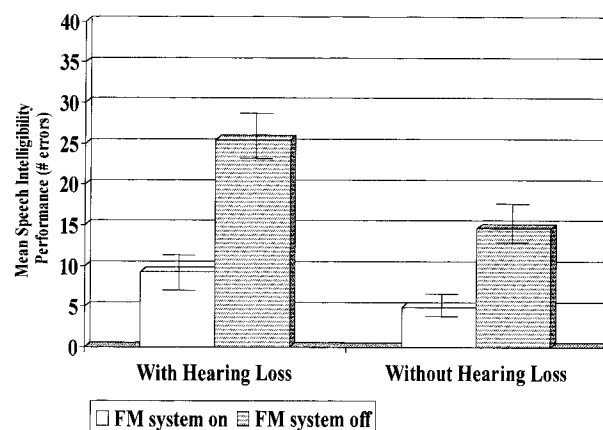


Table 4. Speech intelligibility results for individual students with hearing loss.

| <i>Subject</i> | <i>Age</i> | <i>Grade</i> | <i>PTA left ear^a</i> | <i>PTA right ear^a</i> | <i>Number of errors with system off</i> | <i>Number of errors with system on</i> | <i>Difference off-on</i> |
|----------------|------------|--------------|-------------------------------------|--------------------------------------|---|--|----------------------------------|
| Boy | 7:11 | 2 Inuttitut | 35 | 31 | 33 | 5 | 28 |
| Girl | 7:11 | 2 Inuttitut | 42 | 30 | 29 | 11 | 18 |
| Boy | 8:1 | 2 Inuttitut | 27 | 35 | 21 | 9 | 12 |
| Girl | 8:5 | 3 English | 42 | 46 | 28 | 15 | 13 |
| Boy | 8:7 | 2 Inuttitut | 40 | 42 | 28 | 13 | 15 |
| Boy | 9:4 | 3 English | 39 | 42 | 23 | 11 | 12 |
| Girl | 9:11 | 3 English | 31 | 55 | 31 | 13 | 18 |
| Boy | 10:8 | 5 French | 30 | 42 | 29 | 4 | 25 |
| Boy | 11:7 | 5 French | 32 | 25 | 18 | 8 | 10 |
| Girl | 11:11 | 6 French | 30 | 26 | 15 | 4 | 11 |
| Mean | 9:2 | | 34.8 (30.8–38.8) ^b | 37.4 (30.5–44.3) ^b | 25.5 (21.3–29.7) ^b | 9.3 (6.5–12.1) ^b | 16.2 (11.8–20.6) ^b |

Note. PTA = pure tone average.

^a PTA (dBHL) average of .5, 1, 2, 4 kHz. ^b 95% confidence interval.

Table 5. Speech intelligibility results for individual students without hearing loss.

| <i>Subject</i> | <i>Age</i> | <i>Grade</i> | <i>PTA left ear^a</i> | <i>PTA right ear^a</i> | <i>Number of errors with system off</i> | <i>Number of errors with system on</i> | <i>Difference off-on</i> |
|----------------|------------|--------------|-------------------------------------|--------------------------------------|---|--|--------------------------------|
| Girl | 7:4 | 2 Inuttitut | 14 | 15 | 9 | 2 | 7 |
| Boy | 8:0 | 2 Inuttitut | 16 | 15 | 9 | 2 | 7 |
| Boy | 8:1 | 2 Inuttitut | 10 | 10 | 8 | 0 | 8 |
| Girl | 8:3 | 3 English | 12 | 9 | 11 | 5 | 6 |
| Girl | 8:7 | 3 French | 12 | 15 | 20 | 6 | 14 |
| Boy | 9:11 | 4 French | 10 | 6 | 23 | 7 | 16 |
| Girl | 9:10 | 4 French | 16 | 14 | 15 | 4 | 11 |
| Girl | 10:2 | 4 French | 7 | 12 | 16 | 7 | 9 |
| Boy | 10:11 | 5 English | 9 | 7 | 18 | 10 | 8 |
| Girl | 11:3 | 5 French | 11 | 14 | 17 | 6 | 11 |
| Mean | 9:2 | | 11.7 (9.6–13.6) ^b | 11.7 (9.2–14.2) ^b | 14.6 (10.9–18.3) ^b | 4.9 (2.8–7.0) ^b | 9.7 (7.3–12.0) ^b |

Note. PTA = pure tone average.

^a PTA (dBHL) average of .5, 1, 2, 4 kHz. ^b 95% confidence interval.

As shown in Tables 4 and 5, confidence intervals (CIs) were obtained to represent the range of values encompassing the sample mean and to describe the magnitude and the precision of the effects under consideration. Computations show that the 95% CI derived from students with hearing impairments with the system turned on was 6.5–12.1. Thus, the probability is 95% that this interval contains the true frequency of errors for this population. By contrast, the CI for the same students with the system turned off is 21.3–29.7. Because the CI for the difference in scores does not include 0 in its range, there is 95% certainty that the frequencies of errors with the system off versus on represent two distinct distributions.

A similar picture emerged with regard to CIs for students with no hearing impairment when the system was on (2.8–7.0) versus off (10.9–18.3). In both situations, the direction of effects is clear. Regardless of hearing status,

system off is associated with a greater frequency of errors as compared to system on. The group of students with hearing loss demonstrated an average improvement in speech intelligibility scores of 39% with the system on, whereas the group of students with normal hearing demonstrated a 23% improvement in performance with the system on. A *t* test for independent samples showed a significant difference in performance between the two groups of children ($t(18) = 2.97, p < .01$), indicating that the number of errors was significantly greater for the students with hearing loss than for students with normal hearing on these measures.

Behavioral Observations

Data from the behavioral observation phase of the study were based on 7 of the 10 students with hearing loss or

behavioral difficulties. As with speech intelligibility measures, behavioral observation data also met the normal distribution and homogeneity assumptions for statistical analysis using *t* tests, as previously described. Although the magnitude of increases varied, all four categories of attending behaviors were influenced by the use of the amplification systems in the same direction. A collapsed score for the four attending behaviors was therefore calculated in order to examine the global construct of attending behavior. A *t* test for paired samples comparing the total collapsed scores for the pre- and post-conditions showed a significant improvement in collapsed attending behavior scores with the sound field systems in place ($t(6) = -2.53, p < .05$) as compared to the unamplified condition. A significant difference in total score for body orientation ($t(6) = -2.81, p < .05$) was also noted across the two time periods, whereas comparisons of pre- and post-scores for the other three behavioral categories were not significant. Total scores for the four categories of attending behaviors and the collapsed total score across all four behavioral categories for the group of seven students with hearing loss or behavioral difficulties are presented in Table 6.

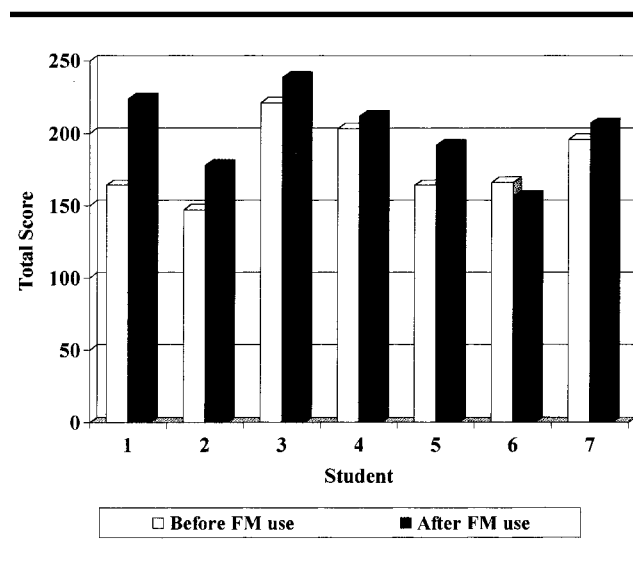
Individual students' total collapsed scores for on-task behavior prior to the installation of the system and with the system in place are provided in Figure 2. In addition, raw data for each student by each attending behavior are presented in Table 7. Student 6 was the only student for whom total on-task behavior decreased rather than increased in the amplified condition. As illustrated in Figure 2, individual students had different patterns of attending behaviors across the behavioral categories of watching the teacher, orienting body to the teacher, absence of extraneous body movement, and absence of extraneous talk to peers. All students demonstrated improvement in at least one behavioral category, with some students improving in all four attending behaviors. Students 1 and 3, Grade 2 students with hearing loss and normal hearing, respectively, showed improvements in all four categories of attending behavior. Student 2, a Grade 2 student with behavioral difficulties, improved in all categories except watching the teacher. Student 4, a Grade 3 student with hearing loss who used a hearing aid, improved only in the category of not moving. Student 5, a Grade 3 student with normal hearing and attentional problems, improved in all categories except

Table 6. Frequency of behaviors for four categories of attending behavior for seven students in unamplified versus amplified conditions.

| | <i>Unamplified condition</i> | <i>Amplified condition</i> | <i>Significance level</i> |
|------------------|------------------------------|----------------------------|---------------------------|
| Watching teacher | 268 | 297 | n.s. |
| Body orientation | 344 | 390 | $p < .05$ |
| Movement | 299 | 332 | n.s. |
| Talk | 350 | 389 | n.s. |
| Collapsed score | 1261 | 1408 | $p < .05$ |

Note. n.s. = not significant.

Figure 2. Total scores for on-task behavior of individual students in amplified and unamplified conditions.



not talking. Student 6, a secondary student with an attention problem and fluctuating hearing loss, improved in the category of body orientation. Student 7, a secondary student with attentional difficulties, did better in all categories except not moving.

Teacher and Student Comments

In their interviews, teachers reported that they found the sound field equipment to be durable and reliable. Neither teachers nor students exhibited any reluctance to use the technology. Areas of improvement mentioned by all participating teachers included increased attention in large group lessons, more rapid student response times, increased involvement in class discussions, less need for repetition of presented material, improved listening skills, and less teacher fatigue at the end of the day.

With regard to the appropriateness of sound field amplification systems for Inuit teachers and students, the Inuit Grade 2 teacher reported that she felt that her students were able to hear Inuttitut word endings more clearly with amplification, resulting in better written Inuttitut. She did not consider that the use of the system interfered in any way with her ways of organizing interaction in the classroom, as noted in the following comment:

I don't think the system changes my way of teaching. There's no need to adapt it for Inuit teachers. We managed to work well even with two teachers in the classroom. If I thought it interfered with my teaching I wouldn't have used it.

The Grade 2 teacher and the teacher's aid transmitted on separate frequencies. No problems were noted with this arrangement.

Teachers in the two second language classrooms also noted benefits of sound field amplification. In their interviews, these teachers mentioned that new words were

Table 7. Percentage of time spent on-task prior to installation of the system (pre) and with the system in place (post) for individual students.

| Attending behavior | Student 1 Grade 2 hearing loss | | Student 2 Grade 2 behavior problem | | Student 3 Grade 2 excellent student | | Student 4 Grade 3 hearing loss | | Student 5 Grade 3 learning difficulties | | Student 6 Secondary 1 fluctuating loss | | Student 7 Secondary 1 attention problem | |
|--------------------|--------------------------------------|------|--|------|---|-------|--------------------------------------|------|---|------|--|------|---|------|
| | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| | Watching | 73.3 | 90.0 | 50.0 | 50.0 | 86.7 | 98.3 | 71.7 | 70.0 | 40.0 | 76.7 | 53.3 | 31.7 | 71.7 |
| Body oriented | 68.3 | 96.7 | 76.7 | 90.0 | 95.0 | 100.0 | 98.3 | 98.3 | 71.7 | 80.0 | 73.3 | 93.3 | 90.0 | 91.7 |
| Not moving | 58.3 | 93.3 | 60.0 | 68.3 | 95.0 | 100.0 | 70.0 | 90.0 | 70.0 | 75.0 | 60.0 | 43.3 | 85.0 | 83.3 |
| Not talking | 73.3 | 93.3 | 65.0 | 88.3 | 91.7 | 100.0 | 98.3 | 95.0 | 91.7 | 88.3 | 90.0 | 91.7 | 80.0 | 91.7 |

learned more quickly and that students participated more actively in instructional interactions. The Grade 3 teacher reported better dictation scores using the system, and one of the two secondary teachers noted that students had better scores on quizzes based on student projects presented with the system in use as compared to presentations where the system was not used.

Although, in general, all teachers used the systems consistently in the classroom, the teachers in the multilevel classroom used their system less often than the elementary teachers. The use of the system in this classroom was influenced by the fact that these teachers had to remember to turn the system off when a single grade level was being taught. According to teacher reports, the secondary students frequently reminded the teacher to turn the system back on for group instruction.

Specific comments transcribed from the interviews with the participating teachers included the following:

The system was really excellent for P. (a student with a mild bilateral hearing loss). Her face really lit up when it was on. She came to school more often also. She could really hear better, and she had a real taste for learning. She could answer questions better and I didn't have to repeat as often. Also she could follow along better since she didn't always have to look at me. The system was also good for the other students. I could get their attention more easily and they had better concentration and better listening skills. (Secondary 1 teacher)

I found their comprehension in English really improved. The exposure to the second language is better through the system. Students aren't guessing the words, they get them the first time. I would like to keep the system and see what it would be like to start out the year with it. I think it would be especially helpful for the students in their beginning experience with the second language. They could get the sounds and the words correctly right from the start. They may also be more willing to speak in English. For me personally one of the big benefits was in terms of my voice. I wasn't hoarse at the end of the day. It's challenging to be the only language model in the classroom—it means we have to talk a lot. The system really made a difference. I was less tired physically using it. (Grade 3 teacher)

When the students heard you were coming to take the system out, they wanted to hide it so you wouldn't take it. They really

like it. Also, I never knew that kids with normal hearing would have trouble hearing with the noise in the classroom. But even the kids with normal hearing had mistakes in Hannah's listening test. That really got to me. I never thought about this before, that maybe some of the kids have difficulties hearing in class even if they have normal hearing. (Inuit Grade 2 teacher)

Student comments regarding the system from the various age groupings included:

I really liked the system.

I was able to hear better in class.

It was really good for learning French. I could learn new words more quickly and follow directions better.

It helped me to hear better during the student presentations.

We would like to keep it. It helped us to learn better.

In summary, sound field systems were found to improve students' scores on the speech intelligibility measures developed for the study and to contribute to positive changes in student attending behaviors. The special circumstances found in classrooms of Nunavik—including team teaching, multilevel classrooms, the second language teaching environment, and the group-orientated teaching style of Inuit teachers—did not prove to be hindrances to the use of sound field amplification. Comments showed that the systems were well accepted by both teachers and students. All three systems were purchased by the school following the trial period and were left in the classrooms for the duration of the academic year.

DISCUSSION AND CONCLUSIONS

Twenty-six percent of the students enrolled in the school where the project was carried out were found to have significant hearing loss in either one or both ears associated primarily with OM. These results are substantially higher than the prevalence of 3 in 1,000 children at age 11 years who continue to experience conductive or recurrent

OM as recently reported by Matkin and Wilcox (1999). Given the high prevalence of OM and hearing loss in the school-aged Inuit population, optimal listening conditions are of extreme importance in the classroom. There are students with hearing loss in almost every class in Nunavik; however, as many as 90% of these students do not use personal amplification. Generally, students with unilateral losses and minimal hearing losses are not fit with hearing aids due to the nature of middle ear disease. The use of sound field systems has the potential to improve classroom listening conditions and make the voice of the teacher more accessible for these students, as well as for those students who use hearing aids.

Measures of classroom acoustics carried out as part of the study indicated that classroom noise was present at levels that could substantially interfere with the speech perception abilities of students with normal hearing, and students with hearing loss would be expected to experience even greater difficulties. Noise levels in occupied classrooms were substantially higher than the 30 dBA noise level recommended for classrooms (Crandell, 1991; Finitzo, 1988), but were similar to those found in other studies (Bess, Sinclair, & Riggs, 1984; Crandell & Smaldino, 1994; Finitzo, 1988). Without amplification, the SNRs of teachers' voice levels in occupied classrooms were significantly lower than the SNR of +15 dB for classrooms that is recommended by the American Speech-Language-Hearing Association (1995).

Installation of the sound field amplification systems led to an improvement in SNR; however, the recommended level of SNR was achieved in only one of the three classrooms, that of the secondary students. This classroom was larger and contained fewer students than did the two elementary classrooms. The younger students also generated higher levels of background noise in the classroom than did the older students. With these noise levels, normal hearing students also benefited from the improvement in SNR. No students complained that the system was "too loud."

Significant improvements in performance on a speech intelligibility task in noise were obtained for groups of students both with and without hearing loss using sound field amplification. Students with hearing loss showed greater improvement in performance with amplification as compared to their peers with normal hearing on the speech intelligibility measures. These findings provide further evidence for the usefulness of classroom amplification in improving classroom listening conditions for students with and without hearing difficulties. Although a significant statistical difference in performance was found between the two groups of students on the speech intelligibility measures, interpreting the clinical significance of this remains difficult because the speech intelligibility measures for Inuttitut syllables have not been standardized. Further research using these measures is needed in order to determine the minimal meaningful difference in speech intelligibility score that would represent an educationally significant change in listening performance in the classroom.

Results from the behavioral observation component of the study showed that total collapsed scores on four categories of attending behavior for the seven students who

participated in this phase of the project improved significantly with the sound field amplification systems in place. Significant improvements related to the behavioral category of body orientation were also observed. Data from individual students presented different patterns of attending behaviors; however, all students showed improvements in at least one of the behavioral categories observed, and all but one student improved in the total score for attending behaviors with the amplification systems in place.

It is possible that the failure to obtain significant differences in all four attending behaviors for all students in the amplified versus the unamplified condition is due to the nature of the behavioral categories used, which may not have been sufficiently detailed to capture more subtle changes in listening behavior in individual students. Videotaped, rather than on-line, scoring of student attending behaviors might have permitted the identification of alternative objective criteria for the measurement of student attending behavior, as well as offered the opportunity to assess the reliability of scoring. However, the use of videotaping was deemed to be excessively intrusive in these classrooms. It is also possible that the SNR obtained with the amplification systems in use might have been too low to result in observable changes in the attending behaviors used in the pilot study, particularly in the elementary classrooms.

The interval sampling procedure used in the behavioral observation phase of the study allowed for only the presence or absence of the four attending behaviors to be recorded. Because multiple occurrences of the same behavior usually are not distinguished in time sampling techniques, information regarding the frequency and duration of the observed behaviors was not obtained. However, the interval sampling technique did permit representative observations of the spontaneous behaviors of the selected students prior to the installation of the systems and with the systems in place to be obtained in a manner that entailed the least possible disruption of natural classroom routines and interactions.

The sound field systems were well accepted and regularly used in all three classrooms; however, teachers in the multilevel secondary classroom used the system less often than did the elementary level teachers. This may have been a result of the increased need to turn the system on and off in order to deal with the frequent changes in whole group versus individual participation structures that were typical of the secondary classroom observed as part of the study. Further investigation of the use of sound field amplification in other classrooms of secondary students would clarify issues related to their usefulness in instructional contexts associated with older learners. Some sound field FM manufacturers offer pass-around and wireless microphones designed to pick up the voices of individual students, as well as conference microphones that can be used to amplify group teaching situations. These types of microphones might be used appropriately in classrooms of older students, where instruction is often oriented toward group discussion of curriculum-related topics.

The potential benefits of sound field amplification for second language classrooms were documented in both

teacher and student comments stating that new words were learned more quickly and that students participated more in discussions in the second language when the system was used. Teachers also mentioned benefits related to decreased fatigue and vocal strain as a result of the systems.

The use of sound field amplification was not found to have interfered with the interaction patterns of the two Inuit teachers who used instructional practices similar to those documented in other classrooms of Inuit teachers. These teachers continued to promote Inuit cultural values regarding appropriate communicative roles for children in the classroom through their use of discourse patterns and instructional sequences that emphasized successful integration into the peer group and behavior respectful of group membership. The teachers did not feel that amplification of their voices overemphasized the regulatory role of the teacher in the classroom in a way that might be culturally inappropriate, nor did they feel that the use of the systems affected appropriate participation structures for Inuit students in the classroom. More extensive research in multicultural classrooms, as well as in classrooms of second language learners, using objective measures of educational outcome would be needed in order to document those aspects of language learning that are most susceptible to improvement through sound field FM use.

The present study entailed five limitations.

1. A between-subjects control group was not used. Future research could incorporate this to examine the effects under consideration when the order of presentation of conditions is controlled. However, within-subjects control conditions (on versus off) did permit reasonable inferences to be drawn concerning the effects of amplification for a group of students who are exposed to both conditions.
2. The high cost associated with transportation to Nunavik allowed for only three trips to be made to the community, and also limited the type of equipment used. In order that trips be used most effectively during the course of the study, it was not possible for both researchers to be present in the community simultaneously. As a result, the behavioral observation portion of the study was conducted by a single researcher, and measures of interobserver reliability related to the scoring of attending behaviors were not obtainable.
3. Tape recorders found in the school were used for the speech intelligibility test, and the frequency response of the tape recorder speakers was not measured. Equipment limitations did not permit measures of gain to be made when the sound field equipment was initially installed. As a result, the decision was made to set the amplifiers and tone controls at mid-position. A higher setting might have resulted in more gain and more measurable positive effects related to the classroom amplification systems.
4. Although significant changes in speech intelligibility and attending behavior scores were found, the generalizability of these findings is limited as a result of the small sample size.
5. The goals of the project did not include the documentation of specific learning outcomes associated with sound field amplification. Given these limitations, results should be considered as preliminary.

Results of the pilot project nevertheless contribute to research illustrating the benefits of sound field amplification for students with hearing, attentional, or behavioral difficulties; students with normal hearing; and second language learners. Furthermore, results of the study indicate that classroom amplification systems appear to be adaptable to classrooms where instructional practices are organized in ways that differ from those that are typical of mainstream educational interactions. These findings point to important potential benefits for classrooms of minority teachers and students, and particularly for those minority students who are at increased risk for auditory difficulties. Further investigation of the appropriateness of sound field amplification in other non-mainstream classrooms, as well as longitudinal studies documenting first and second language learning outcomes in amplified versus unamplified classrooms, would provide increased support for the adoption of sound field amplification systems as a sound and desirable educational option.

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