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SOUND-FIELD AMPLIFICATION: ENHANCING the CLASSROOM LISTENING ENVIRONMENT for ABORIGINAL and TORRES STRAIT ISLANDER CHILDREN

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Abstract

Sound-field amplification is an educational tool that allows control of the acoustic environment in a classroom. Teachers wear small microphones that transmit sound to a receiver system attached to loudspeakers around the classroom. The goal of sound-field amplification is to amplify the teacher's voice by a few decibels, and to provide uniform amplification throughout the classroom without making speech too loud for normal hearing children. This report discusses the major findings of a study which investigated the effects of sound-field amplification intervention on the communication naturally occurring in the classrooms of Aboriginal and Torres Strait Islander children. The audiological findings of the sample population of children are presented, as well as details of the classroom acoustic environment. Sixty-seven percent of the children began the field trials with a slight hearing loss. The results confirmed the extremely noisy and reverberant conditions in which teachers and children are operating on a daily basis. The findings indicated that sound-field amplification intervention encouraged the children to interact with teachers and peers in a proactive way. Teachers identified voice-related factors to be a major personal benefit of the systems.

Introduction

The classroom serves as a communication channel for listening and learning. Unfortunately, the typical classroom can provide a hostile listening and learning environment for both teachers and students. Sound-field amplification is an educational tool that allows control of the acoustic environment in a classroom. This paper discusses the major findings of a study which investigated the effects of sound-field amplification intervention on the communication naturally occurring in the classrooms of Aboriginal and Torres Strait Islander children in Cherbourg and Yarrabah, Queensland.

Background: Barriers to effective communication in the classroom

The goal of classroom instruction is comprehension. However, for speech to be comprehended, the child must be able to hear well enough to discriminate the word-sound distinctions of individual phonemes. Normal hearing for children is now considered to be 15 decibels hearing level (dB HL) or better at all frequencies, and with normal middle ear function (Northern & Downs, 2002). A slight hearing loss extends from 16 to 25 dB HL. Studies have indicated there are significant numbers of children with this degree of unidentified hearing loss in every school, many as a result of middle ear problems (Flexer, 1992). Unfortunately, the term "slight hearing loss" erroneously implies that the loss has little consequence. This is not the case. The high prevalence of early onset, long-term middle ear disease and consequent hearing loss amongst Aboriginal and Torres Strait Islander children has been well documented (McPherson, 1990; Nienhuys et al., 1994). Australian studies have indicated that 50% to 80% of Aboriginal and Torres Strait Islander school children have sufficient middle-ear related hearing loss to adversely affect classroom performance (Nienhuys, 1994).

In addition to hearing problems, the combination of excessive noise and reverberant classrooms contributes to the difficulties faced by all school children in understanding the teacher's verbal instruction. The teacher's voice may be so poor at the child's ear that the speech is masked by the noise, a term known as the

"signal-to-noise" ratio (S/N ratio). Flexer (2002) referred to the recently adopted United States national acoustical standards (American National Standards Institute, 2002) which calls for unoccupied classroom noise levels to be less than 35 dB, and reverberation time (RT) (the amount of "echo" in the room) to be less than 0.6 seconds for medium size rooms. The recommended S/N ratio in a classroom for young learners is +15 dB (American Speech-Language-Hearing Association, 1995). Teachers working in noisy classrooms must constantly raise their voices in response to varying levels of background noise to achieve this S/N ratio, thus producing vocal strain. Gotaas and Starr (1993) found that 80% of teachers reported vocal fatigue compared to 5% of the general population.

According to the literature, classroom communication for the Aboriginal and Torres Strait Islander child is a complex interaction of cultural influences, language mismatch and different learning preferences. Non-Indigenous teachers bring different expectations and interpretations to the classroom which may lead to misunderstandings (Kearins, 1985). Language differences can be a major barrier to effective classroom participation (Lowell, 1993). As formal Western education is traditionally heavily dependent on verbal language, any mismatch will mean the Aboriginal and Torres Strait Islander child will have difficulty predicting or filling in the language gaps, particularly when hearing under adverse listening conditions and with a hearing impairment (Burnip, 1994). This can affect the child's emotional world, and lead to feelings of inadequacy and failure (Sherwood & McConville, 1994). Additionally, Aboriginal and Torres Strait Islander children's learning preferences are informal and less reliant on verbal interaction as the predominant medium of learning (Lowell, 1993; West, 1994). Peer interaction is an important source of communication and learning, and children naturally learn through observing their peers and being helped by peers (Howard, 1994). Such behaviours contrast with the Western educational approach of paying attention to the teacher.

What is sound-field amplification?

Sound-field amplification has also been termed "classroom amplification" and, more recently, "sound-field distribution systems" (Flexer, 2002). Teachers wear small microphones that transmit sound to a receiver system attached to loudspeakers around the classroom. The goal of sound-field amplification is to amplify the teacher's voice by approximately 8 to 10 dB, and to provide uniform amplification throughout the classroom without making speech too loud for normal hearing children (Crandell, 1998).

Originally designed as an assistive technology for children with mild hearing loss, research in the United States over the past 20 years has shown that sound-field amplification benefits all children. The benefits have included improved academic achievement, speech recognition, attending skills, and learning behaviours (Rosenberg & Blake-Rahter, 1995). Benefits identified for teachers include reduced vocal strain and vocal fatigue, increased ease of teaching, increased versatility of instructional techniques, and increased teacher mobility (Rosenberg et al., 1999).

In the early 1990s, the National Acoustic Laboratories (NAL), the research arm of Australian Hearing, developed a dual-channel sound-field amplification system with the needs of Aboriginal and Torres Strait Islander children living in both remote Australian communities and urban areas in mind (Page, 1995). The first of these systems was installed in four schools in North Queensland in 1992. Two of the systems were installed at schools in Aboriginal and Torres Strait Islander communities in the Gulf of Carpentaria. The other two systems were installed at a school north of Cairns which had a high proportion of Indigenous students. Page et al. (1995) outlined the following benefits based on teacher comments:

- the children were less distracted;
- it was easier to gain the children's attention;
- there was lack of shame associated with using the system for the whole class compared with devices for individuals; and,
- children with normal hearing appeared to benefit.

The teachers also reported significantly less voice strain and feeling less tired at the end of the day. Loades (1993), reporting on a trial of classroom amplification at two Aboriginal schools in western South Australia, found there was not as much variation of "time on task" behaviours compared with individual FM amplification systems. In a trial performed at a school with a high proportion of Aboriginal kindergarten children in New South Wales, Dowell (1995) reported improvements in listening behaviour during the six month period. While anecdotal evidence and the findings from these few Australian investigations suggest benefits, the present research programme was the first quantitative investigation on the efficacy of sound-field intervention in the classrooms of Aboriginal and Torres Strait Islander children.

Research questions

This study aimed to examine the following questions:

- What was the hearing status of a sample population of Indigenous school children?
- What were the acoustic characteristics of the classrooms and what levels of amplification were produced in the field?
- What were the effects of sound-field amplification intervention on the communication occurring between the teachers and the children?

Procedure

An eight-week field trial of sound-field amplification was carried out in four classrooms, two in each of the rural Queensland communities of Cherbourg and Yarrabah. These communities were chosen for their accessibility and diversity of lifestyle. Cherbourg is the closest rural Indigenous community to Brisbane, the capital city of Queensland. Located a few kilometres from the large town of Murgon, the people lead modern lifestyles. Yarrabah is a North Queensland coastal Aboriginal community with some Torres Strait Islanders within the community. It is located within driving distance from Cairns, a major urban centre. This research programme adhered to the ethical research guidelines issued by the National Health and Medical Research Council issued in 1992 and published in 1993. Ethical clearance for this project was obtained from the ethics committee at the University of Queensland. Of the 64 children participating in the study, 48% were males and 52% were females. The ages of the 64 subjects ranges from 6 years 1 month to 10 years 3 months (M=8 years 2 months). One Year 2 class, two Year 3 classes, and one Year 5 class participated in the study. Of the two female teachers at Cherbourg State School who volunteered to participate in the study, one was a new graduate who had lived in Cherbourg community all her life and was of Aboriginal and Torres Strait Islander descent. The other teacher was non-Indigenous with over 13 years teaching experience with Indigenous children, eight of which had been at Cherbourg State School. At Yarrabah State School, both classes had non-Indigenous teachers. One volunteer teacher, a female, had one and a half years teaching experience. The fourth teacher was a male with three years teaching experience, all of which had been with Indigenous children.

The listening environments of the four classrooms were alternated between unamplified "OFF" and amplified "ON" conditions at two-weekly intervals over the eight week period. Hearing tests were performed on the 64 children. Acoustic measurements, including ambient noise levels, reverberation times (RT) and S/N ratios, were obtained for each classroom. Structured classroom observation was used to record the communicative interactions occurring spontaneously between the children, teachers and peers. A modified Environmental Communication Profile, originally developed by Calvert and Murray (1985), was used by trained observers to record the communicative interactions occurring between the child, teacher and peers simultaneously.

Two self-report instruments were used in the study. These were the Screening Identification for Targeting Educational Risk (S.I.F.T.E.R.) rating scale (Anderson, 1989) and a teacher questionnaire devised for the study. The former is the most widely used protocol to measure the efficacy of sound-field amplification (Crandell, 1998) and focuses on the teacher's observation of classroom performance in relation to listening skills. The teachers were asked to rate each child before and after the sound-field amplification trials in the performance subtests of academic performance, attention, communication, class participation and school behaviour. Each teacher was asked to complete the teacher questionnaire at the end of the field trials.

Results

Audiological results

The mean pure tone average hearing level for this population of children was 20 dB pre-trials, and 19 dB post-trials. These levels fall into the category of slight hearing loss, as defined by Clark (1981). Twenty percent of the children began the trials with normal hearing levels, and 67% of the children began the trials with slight hearing loss levels in the 16 to 25 dB range. Eight percent of children had mild hearing loss (between 26 and 40 dB) and 5% of children had moderate hearing loss (between 41 and 55 dB).

Classroom acoustic measurements

Each of the classrooms demonstrated extremely noisy listening conditions. Classroom noise levels and reverberation times were very high relative to recommended levels (Table 1). All the mean S/N ratios were in the negative range under normal listening conditions (see above), indicating the teacher's voice was softer than the noise levels usually found inside and outside the classrooms.

Classroom communication

The observational data were combined and compared to determine whether the effects of the amplification

Table 1. Results of acoustic measurements for each classroom (dB=decibels).

Classroom	Noise levels (occupied)	Mean RT (unoccupied)	Mean S/N (unamplified)	Mean S/N (amplified)
Classroom 1	62 dB	1.8 seconds	-3 dB	+3 dB
Classroom 2	67 dB	1.3 seconds	-2 dB	+2 dB
Classroom 3	72 dB	1.7 seconds	-9 dB	+1 dB
Classroom 4	75 dB	1.8 seconds	-9 dB	-4 dB

intervention occurred immediately (over a two-week time span), in the short-term (over a four-week time span), or whether the effects were cumulative (at the end of the field trials). The results showed there were no significant changes in the dynamics of communication occurring in Class 1, the classroom with the Aboriginal teacher. Conversely in Classes 2, 3 and 4 with non-Indigenous teachers, common significant changes in communicative interactions were demonstrated for each of the temporal comparisons during the field trials.

The results of the immediate comparisons for Classes 2, 3 and 4 indicated:

- an increase in the total number of communicative interactions;
- an increase in child, teacher and peer verbal communication;
- an increase in the number of interactions initiated by the children;
- the children initiated more communication without being directly prompted (Figure 1); and,
- there were trends for the children to initiate more interactions to the teacher, and to respond to communication directed to the entire class.

The results of the short-term comparisons for Classes 2, 3 and 4 indicated:

- an increase in the total number of communicative interactions occurring between the children, teacher and peers;
- an increase in verbal communication between the children, teacher and peers; and,
- an increase in the number of times the children initiated communication.

Comparison of data recorded at the beginning and at the end of the field trials for Classes 2, 3 and 4 indicated:

- an increase in the total number of communicative interactions occurring in each of the classrooms;
- an increase in child and peer verbal communication and total verbal communication (Figure 2); and,
- an increase in the number of times the children initiated communication.

Self-report measures

The results of the S.I.F.T.E.R. rating scale for the four classes indicated the teachers observed improvement in attention and increased class participation following the use of sound-field amplification (Table 2). The former performance subtest relates to the child's distractibility and attention span compared with peers, as well as the child's ability to respond to oral directions. The latter performance subtest refers to how often the child volunteers information to class discussion or in answers to questions, and the amount of difficulty the child has in starting to work after instruction. In addition, a significant improvement in total scores for the five performance subtests was demonstrated pre- and post-trial for all the classes, indicating the teachers considered there had been overall improvement in the areas of academics, attention, communication, class participation and school behaviour (Table 2). Teachers identified voice related factors to be a major personal benefit of the systems.

Significance of findings

The results of this study confirmed the extremely noisy and reverberant listening environments in which both teachers and children are operating on a daily basis, and emphasised the very urgent need for classroom acoustics treatment in conjunction with sound-field amplification installation. The very poor S/N ratios evident in each of the classrooms would have resulted in considerable

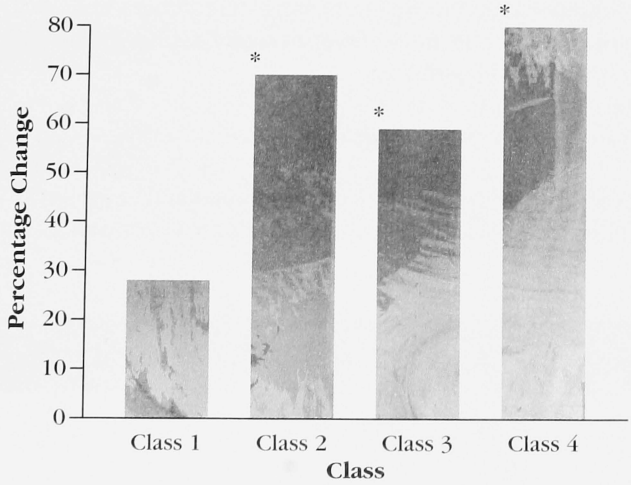

Figure 1 Immediate comparisons per class: Percentage change in the number of communicative interactions initiated by children without prompting (*=p <0.05).

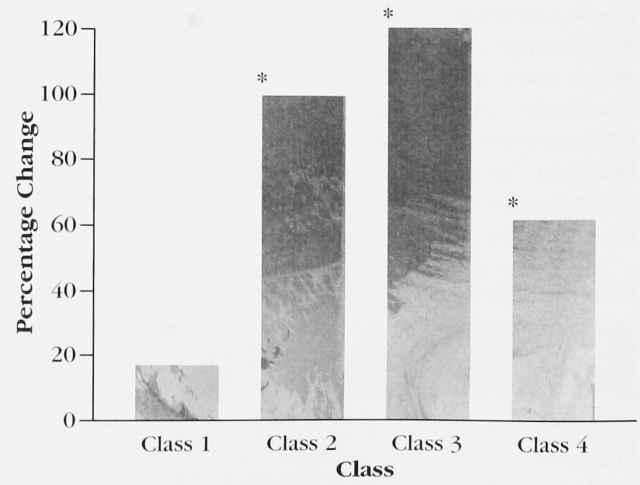

Figure 2. Percentage change in "total verbal communication variable" (child, teacher and peer) for each class from beginning to end of field trials (*=p <0.012).

Table 2. Results of S.I.F.T.E.R. comparisons for the four classes (*=p <0.05).

Performance subtest	Mean (pre-trial)	Standard deviation	Mean (post-trial)	Standard deviation	p*
Academics	9.60	3.94	9.67	4.20	0.742
Attention	8.17	3.57	9.27	3.78	0.001**
Communication	9.70	3.43	9.87	3.79	0.516
Class participation	9.60	3.38	10.40	3.83	0.004**
School behaviour	10.87	3.72	11.32	3.92	0.169
Total score	47.95	15.52	50.52	17.55	0.007**

reduction in speech recognition for all the children. In addition, given that Western education is heavily dependent upon verbal language, the fact that only 20% of the children began the trials with normal hearing levels, and 67% of the children began the trials with slight hearing loss in the 16 to 25 dB HL range would have exacerbated their speech perception difficulties.

The results indicated that improving the classroom listening environments had positive effects on the communication occurring between the teachers and the children. However, few changes in the dynamics of classroom communication were evident for Class 1 during the field trials. It was concluded that, because the Indigenous teacher in Class 1 provided a culturally responsive learning environment, the communication breakdowns reported in the literature to occur in cross-cultural educational settings did not occur in this classroom. The teacher naturally adopted a teaching approach which was less reliant on verbal strategies and teacher-centred learning. Therefore, compared with Classes 2, 3 and 4 which had Western-style teachers, the improved S/N ratio provided by the amplification system had less measurable impact on the communication naturally occurring in the classroom.

For Classes 2, 3 and 4, the results generally showed there was significantly more communication occurring between the teacher, children and peers during the course of the trials, and that the effects were cumulative. The findings suggested the children in these three classes used more verbal language and were playing a more proactive role in classroom communication as the trials progressed. It was concluded that even short and intermittent exposure to an enhanced listening environment fostered the children's confidence and subsequent involvement in classroom interactions, a notion supported in the literature (Grauf, 1994). The results of the S.I.F.T.E.R. rating scale highlighted areas which were also identified as significant in the observational data, these being improvements in the areas of attention and class participation. Another important finding was that teachers indicated they had less vocal strain and felt less fatigued at the end of the day after using the systems. In view of the noisy classroom acoustic conditions under which the teachers taught, this was not surprising, and is congruent with other teacher surveys on sound-field amplification (Anderson, 2001). One of the recurring themes throughout the study was the important role the peer group played in the children's natural communication network. The results of this study confirmed the increase in peer related activities in facilitating the overall increase in responsiveness from the children, and an increase in verbal communication between the children and their peers over time. Given these findings, the question must be asked whether, in the long-term, the improved S/N ratio provided by the sound-field systems would affect learning outcomes of Indigenous Australian children.

Conclusion

Sound-field amplification intervention reduced the deleterious effects of reduced speech perception and encouraged the school children to interact with teachers and peers in a proactive way. At present in Australia, however, there are no clear or enforceable standards for classroom acoustics. Moreover, given that structural acoustic modifications can prove costly per classroom, sound-field amplification may provide a rapid, cost-effective part of the solution to improving the classroom listening environment for all Aboriginal and Torres Strait Islander children.

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References

American National Standards Institute. (2002). *Acoustical performance criteria, design requirements and guidelines for schools*. ANSI S 12.60.

American Speech-Language-Hearing Association. (1995). Position statement and guidelines for acoustics in educational settings. *American Speech-*

Language-Hearing Association, *37*(Supplement 14), 15.

Anderson, K. (1989). *Screening instrument for targeting educational risk (S.I.F.T.E.R.).* Austin, TX: PRO-ED.

Anderson, K. (2001). Voicing concern about noisy classrooms. *Educational Leadership*, April, 77-79.

Burnip, L. (1994). Hearing impairment, phonological awareness, and the acoustic environment of the classroom. *Australian Journal of Remedial Education*, *26*(1), 4-10.

Calvert, M. B., & Murray, S. L. (1985). Environmental communication profile: An assessment procedure. In C. S. Simon (Ed.), *Communication skills and classroom success: Assessment of language-learning disabled students* (pp. 135-159). London: Taylor & Francis.

Clark, J. G. (1981). Uses and abuses of hearing loss classification. *American Speech-Language-Hearing Association*, *23*, 493-500.

Crandell, C. (1998). Using sound-field FM amplification in the educational setting. *The Hearing Journal*, *5*(5), 10-19.

Dowell, J. (1995). Trial of sound-field amplification system. *Proceedings of the OtitisvMedia NSW Conference 1995 – Its implications for Aboriginal and Torres Strait Islander people*. Sydney: New South Wales Department of Health, New South Wales Department of School Education, New South Wales Board of Studies.

Flexer, C. (1992). FM classroom public address systems. In M. Ross (Ed.), *FM auditory training systems: Characteristics, selection and us* (pp. 189-206). Timonium, MD: York Press.

Flexer, C. (2002). Rationale and use of sound field systems: An update. *The Hearing Journal*, *55*(8), 10-18.

Gotaas, C., & Starr, C. (1993). Vocal fatigue among teachers. *Folia Phoniatrica et Logopaedica (Basel)*, *45*, 120-129.

Grauf, N. (1994). *Report on whole class amplification systems installed in Cape and Gulf schools*. Cairns, QLD: Torres Strait, Cape and Gulf School Support Centre.

Howard, D. (1994). Culturally responsive classrooms: A way to assist Aboriginal students with hearing loss in urban schools. In S. Harris & M. Malin (Eds.), *Aboriginal kids in urban classrooms* (pp. 37-51). Darwin: Social Science Press.

Kearins, J. (1985). Cross-cultural misunderstandings in education. In J. B. Pride (Ed.), *Cross-cultural encounters: Communication and mis-communication* (pp. 65-79). Melbourne: River Seine Publications.

Loades, C. (1993). Western Australia centre for hearing impaired children, Aboriginal hearing program. In *Otitis media in childhood: Issues, consequences and management: Proceedings of the Western Australian Otitis Media Group conference* (pp. 253-268). Perth, WA: Western Australia Otitis Media Group Inc.

Lowell, A. (1993). Otitis media and classroom communication. *Australian Communication Quarterly*, 11-13.

McPherson, B. (1990). Hearing loss in Australian Aborigines: A critical evaluation. *The Australian Journal of Audiology*, *12*, 67-78.

Nienhuys, T. (1994). Aboriginal conductive hearing loss for life. *Australian Language Matters*, *2*(1), 8-9.

Nienhuys, T. G., Boswell, J. B., & McConnell, F. B. (1994). Middle ear measures as predictors of hearing loss in Australian Aboriginal children. *International Journal of Pediatric Otorhinolaryngology*, *30*, 15-27.

Northern, J. L., & Downs, M. P. (2002). *Hearing in children* (54th ed.). Baltimore: Lippincott Williams and Wilkins.

Page, S. (1995). *Dual FM sound field amplification: A flexible integrated classroom amplification system for mild to moderate conductive hearing loss*. Unpublished manuscript.

Page, S., Hatfield, A., & Wallington, J. (1995). Sound-field amplification: Alternative technology for minimal hearing loss. In *Otitis media in childhood: Issues, consequences and management: Proceedings of the Western Australian Otitis Media Group conference* (pp. 338-334). Perth, WA: Western Australia Otitis Media Group Inc.

Rosenberg, G., & Blake-Rahter, P. (1995). Sound-field amplification: A review of the literature. *Sound-field FM amplification: Theory and practical applications* (pp. 107-123). San Diego, CA: Singular Publishing Group Inc.

Rosenberg, G., Blake-Rahter, P., Heavner, J., Allen, L., Redmond, B., Phillips, J., et al. (1999). Improving classroom acoustics (ICA): A three year FM sound-field classroom amplification study. *Journal of Educational Audiology*, *7*, 8-28.

Sherwood, J., & McConville, T. K. (1994). *Otitis media and Aboriginal children: A handbook for teachers and communities*. North Sydney: NSW Board of Studies.

West, L. (1994). Cultural behaviour, conflict and resolution. In S. Harris & M. Malin (Eds.), *Aboriginal kids in urban classrooms* (pp. 7-19). Darwin: Social Science Press.

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