Sound Field Amplification in the Classroom: Literature Review

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Classrooms are primarily auditory learning environments. Students of all ages from kindergarten to university must learn to accurately decode and organize the speech signal conveyed by the teacher. However, compared to adults, children require a sharper auditory signal. Because of their under-developed neurological network and lack of listening and life experience, they are not as proficient as adults at performing the automatic filling in of the gaps of missed information. Therefore, children require a quieter environment and a louder speech signal in order to process an auditory signal (Flexer & Long, 2003).

Some children may be facing greater challenges than others. For example, children learning a second language are at an increased risk for speech perception errors. Children learning a second language (L2) have less experience in the language of instruction than children learning in their first language, therefore they are at an even larger disadvantage to fill in the gaps of missed information. This suggests that it would be beneficial to provide L2 children optimal access to a high quality acoustical signal and there is support for this suggestion. Crandell (1996) found that L2 children require a quieter environment and louder signal in order to perform as well as their first language learning (L1) counterparts on tests of speech perception. The topic of second language speech perception will be discussed after a general introduction to past research on acoustics in the mainstream classroom is discussed.

The barriers to providing this sharp auditory signal are commonly found in classrooms. Finitzo-Hieber & Tillman (1978) have shown that children in a good acoustical environment were able to recognize only 71% of test stimuli and the score fell to 30% in typical, acoustically poor classroom listening conditions. This is cause for concern because of society's reliance on a future workforce requiring high levels of language and literacy skills. Since our education system and language and literacy depend on the auditory signal, it is essential to provide a high quality signal for children to use as a building block for phonemic awareness and eventually language and literacy.

In a typical classroom, speech interference from background noise, a low signal to noise ratio (SNR), poor reverberation time (RT) and distance from teacher to student, all interfere with providing a sharp signal for students in the classroom. The interaction between these four variables may also have an even larger negative impact on speech perception in the classroom (Crandell & Smaldino, 2000).

One of these barriers to sharp auditory signals, background noise, includes noise that originates from outside the building and noise that originates from inside the building, including noise that comes from inside the classroom. So, cars passing by, the school's ventilation systems and students talking are all sources of background noise in a classroom. Background noise levels in classrooms have been found to be between 60-65 dbA. This is often much higher than a teacher's speech level and makes it almost impossible for effective listening to occur.

This noise in a classroom affects students' ability to perceive speech by masking the acoustic and linguistic cues that are presented in the teacher's spoken message. It tends to predominantly influence the perception of consonants because the spectral energy of consonants is less intense than vowels. Even minimal consonant perception loss influences accurate speech perception, because we rely primarily on consonants to decode speech (Nabalek, 1982).

A second important factor is the relationship between background noise and signal strength (signal to noise ratio). SNR in classrooms is the relationship between the intensity of the signal and the intensity of the background noise at a person's ear. For example, if the speech signal were recorded at 75 dB, and a noise is 65 dB, the SNR would be +10 dB (Crandell & Smaldino, 2000). The optimal level depends on the age and hearing ability of the student. The American Speech-Language-Hearing Association (ASHA, 1995) has suggested that this relative level in classrooms should be no lower than +15 dB for optimum speech recognition. However SNRs in classrooms have rarely been found to be high enough: most are between +5 to -7 dB (Crandell & Smaldino, 2000).

A third barrier to clear auditory signals is reverberation time (RT). This term refers to the "persistence or prolongation of sound within an enclosure as sound waves reflect off hard surfaces" (Crandell & Smaldino, 2000, p.365). It is defined as the time (in seconds) it takes for the sound from a source to decrease in level by 60 dB after the source has stopped. The problem with reverberant speech is that it reaches the listener after the direct sound and the result is a smearing of the speech signal. Researchers have examined the effects of RT on the perception of consonants and vowels in various word positions. It has been found that weaker, high frequency consonants are often masked by the lower frequency vowels (Nabalek, 1982). It is recommended by ASHA that the RTs for classrooms should not exceed 0.4 seconds (ASHA, 2005). However, studies have found that they usually vary from 0.4 to 1.2 seconds (Crandell & Smaldino, 2000).

A fourth factor affecting speech perception is the distance from the speaker to the listener. When a teacher and student are in close proximity, the teacher's speech dominates the listening environment. However, this sound level decreases according to the principle of the inverse square law. This law states that the sound level decreases 6 dB for every doubling of distance from the sound source (Crandell & Smaldino, 2000). As teachers move farther away from their students, the reverberant sounds begin to dominate the listening environment. The critical distance of a room is the point in the room where the level of the direct sound and the level of reverberant sound are essentially equal. In an average sized classroom, the critical distance would be approximately 3-4 meters from the teacher. As the teacher moves farther away, it becomes increasingly difficult for students to decipher the speech message.

These variables are not independent of one another. When combined, they produce a greater negative impact on speech perception. Crum (1974) studied the effects of background noise, reverberation and distance upon speech intelligibility. He measured the speech intelligibility of 12 college students under differing conditions of background noise (+6 dB and 0 dB), RT (0.0, 0.4, 0.8

and 1.2 seconds) and distance (6, 12 and 24 feet). In the conditions with all three variables (noise, reverberation and distance), the effects were found to be interactive rather than simply additive. The greatest reduction in speech intelligibility was found when all three variables were present.

In the classroom, background noise, SNR, RT and distance from the speaker are also not independent of one another. There is an interaction between them that produces a greater impact than if the effects of the three were added separately (Crandell & Smaldino, 2000). So if a classroom provides an environment with both a poor SNR and a high RT, the reduction in speech perception will be worse than if the effects of the two separately are combined.

Second language learners are at an increased risk of being affected by these variables because of their lack of experience in L2. They must learn the new sounds common to L2 and build their vocabularies accordingly. Crandell and Smaldino (1996) demonstrated that under quiet conditions, when compared to L1 learners, L2 learners scored equally well on a test of speech perception; however, under loud background noise conditions, L2 participants' score dropped significantly more than the L1 learners scores. This suggests that second language learners require an even quieter environment and louder speech signal in order to reach their potential in L2.

Because the above-mentioned speech recognition obstacles are found widely in classrooms, technology that improves the classroom acoustical environment, may provide benefits for students' speech perception and possibly their language and literacy skills. One way to improve the auditory signal in classrooms is through Sound Field Amplification (SFA), a form of amplification technology that has been shown to improve the signal to noise ratio (SNR) that is often too low in classrooms. The teacher wears a microphone that is placed 4-6 inches from the teacher's mouth. It projects her voice from audio speakers that are strategically placed throughout the classroom. The result is that everyone in all locations of the classroom has access to a higher quality acoustical signal. In essence, it makes the teacher's voice stand out more than the background noise originating from inside and outside the classroom. This type of system provides the benefits of optimal access to verbal instruction for children and adults with and without hearing loss. Studies that assess the SFA system's effectiveness under various conditions will be discussed below.

Children, who are especially vulnerable to speech interference may require noise levels to be as low as 28.5 dBA for optimal speech perception (Finitzo-Hieber & Tillman, 1978). Ray, Sarff and Glassford (1984) were among the first to study SFA for mainstream classroom use. The Mainstream Amplification Resource Room Study (MARRS) studied children in grades K-6 who had normal intelligence but who were behind academically by at least six months and they were shown to have minimal hearing loss. Half the children were randomly assigned to amplified classrooms with no extra teacher support and half were randomly assigned to un-amplified classrooms with extra support teaching. By the end of the three-year study, the children in the amplified condition had increased their reading scores, which were equal to or greater than those of the children in the un-amplified condition. The younger the children, the greater were these gains. This study opened the door for others to follow in assessing the benefits of SFA, not only for children with hearing impairments but for those without as well.

The Improving Classroom Acoustics (ICA) special project (Rosenberg, Blake-Rahtner, Heavener, Allen, Redmond, Phillips, 1995) was designed to assess whether listening and learning behaviors, as measured by The Listening and Learning Observation (LLO) and the Evaluation of Classroom Listening Behaviors (ECLB), improved as a result of the presence of SFA systems in the classroom. The LLO includes four sections: Student Data, Listening Behaviors, Academic/Pre-Academic Behaviors, and Academic/Pre-Academic skills, The ECLB is a 10-item observation focused on discrete listening tasks (Rosenberg et al, 1995).

In addition to using the student measures of ECLB and LLO, this study examined the evaluation of the SFA system by students, teachers, parents and school administrators. Two thousand and fifty four students in kindergarten, grade one and grade two general education classes in 33 elementary schools in Florida took part in the study. Half of the classes were assigned to the treatment (SFA system) the other half were assigned to the control condition (no SFA system).

The mean classroom noise levels (when unoccupied) were 47-48 dBA , which is 17 dBA above the ASHA suggested level of 30 dBA. With the SFA system in place, the teachers gained a mean of +6.94 dBA in vocal intensity. SNR was not measured. Pre-, mid- and post-treatment measures were taken using the LLO and ECLB. Students in the amplified classrooms demonstrated an increase in listening and learning behaviors and skills. These increases occurred at a faster rate than for their peers in the un-amplified condition. The authors also noted that teachers, students and administrators provided positive evaluation of the SFA system. For example, teachers reported less vocal fatigue, students reported hearing the teacher more clearly and easily and administrators reported less behavior referrals from classrooms using SFA systems.

Palmer (1998) also examined SFA in the classroom using behavioral measures. Eight children from grades K-2, with normal IQ's took part in the study. Teachers compiled a list of students who they found to have difficulty paying attention in the first weeks of school and from this list, eight children were chosen at random. Palmer chose to study children with difficulty paying attention in order to ensure that the behavioral changes associated with SFA would be measurable. Teacher behavior was also measured to control for changes in their behavior while using SFA.

The researchers measured teacher position, teacher behavior, task management, and competing or inappropriate responses by students. These behaviors were chosen because previous literature suggested that they may be affected by SFA. The teachers were blind to when and which students were being evaluated.

Noise levels in the unoccupied classrooms were between 50 and 53 dBA, 20 dB above the ASHA recommended level of 30 dBA and RT was not measured. When the systems were turned on the

SNR was between +6 and +10 dB SNR. Data was collected using the Code for Instructional Structure and Student Academic Response (CISSAR). This computer software allows an observer to record data on the interaction between situational factors such as amplification on versus off and temporally related child responses such as on versus off task behavior (eco-behavioral interaction) (Palmer, 1998). The design included a baseline measurement, treatment measurement and return to baseline measurement. During the treatment condition, SFA reduced the competing/inappropriate behaviors and increased the occurrence of task management in all eight children. The withdrawal of SFA produced an immediate increase in the competing/inappropriate behaviors. However, task management remained the same during the maintenance stage.

The results of the teacher behavior observations indicate that the SFA didn't have an effect on teacher behavior. The researchers concluded that the effects of the SFA on students' behavior was related to the treatment condition. Teachers also completed a survey about SFA and all the teachers indicated that the SFA had reduced their fatigue, reduced instruction repetition and transition time, and increased control of and attention from students.

Another way to test the benefits of SFA in classrooms is by measuring speech perception in amplified vs un-amplified conditions. Increased speech perception may be the cause of the improved hearing and comprehension and is therefore a useful way to measure the benefits of SFA. The authors did not, however compare the effect of context on speech perception which may more realistically approximate the natural classroom environment. In a longitudinal study to test the benefits of SFA for children in kindergarten and grade one, Mendel, Roberts, and Walton (2003) examined the effect of Sound Field FM systems in seven classrooms using a between-subjects design. They tested speech perception in normal children using recordings of sound from their natural listening environment (their classrooms). Children were tested three times between kindergarten and grade one.

The children with the Sound Field FM equipment present in their classrooms scored significantly higher on the Word Identification by Picture Identification (WIPI) test when tested in the kindergarten-fall and kindergarten-spring sessions but not in the grade one spring testing session. This suggests that although the Sound Field FM equipment provided a head start for those in the treatment condition, the control group caught up by the end of grade one.

Children were also tested on the Phonetically Balanced Kindergarten (PB-K) test in noise. This test measures speech perception. There were no significant effects of group for any of the three test sessions (kindergarten fall, kindergarten spring, and grade one spring). This study also contained a teacher evaluation of the FM system and results showed that there was universal support for the system. Teachers also commented on the positive effects of the FM system on their students, such as an increase in attention. They also noted a decrease in vocal fatigue at the end of the day.

Other studies have assessed SFA system benefits under special circumstances, such as second language learning and in children with hearing impairments. Research on the speech perception in children for whom English is a second language (ESL) suggests that they may also be a population who could benefit from SFA. Crandell and Smaldino (1996) examined 20 children with English as their first language and compared their scores on the Bamford Koval Bench Standard Sentence Test with 20 ESL children in varying listening conditions that are common in classrooms. Both groups were between the ages of eight and ten and were screened for hearing loss. The ESL group started speaking English by age two as reported by their parents.

Results indicate that ESL children performed as well as native English speaking children on sentence perception in quiet conditions; however, they had lower scores on sentence perception, when the SNR deteriorated between +3 and -6. This result was found to be statistically significant at the 0.5 level of probability. Also, the performance by both groups decreased as the SNR decreased and the discrepancy between the groups increased. To illustrate, at +3 SNR, the difference between the groups was only 4%; however at -6 SNR, that difference increased to 25%. This indicates that not only are

ESL children at a greater risk for degraded speech perception at low SNR levels than children for whom English is their native language, but that this difference also becomes more pronounced as the SNR level deteriorates. This implies that in order for ESL children to reach their full potential in the education system, they require a quiet school environment with a good SNR.

In a pilot project by Eriks-Brophy and Aykawa (2000), the benefits of SFA systems were tested in Inuit classrooms. This study examined the FM system in the context of the special circumstances that are present in Nunavik, such as a high percentage of hearing impairments due to chronic Otitis Media and different teaching circumstances such as team teaching, multilevel classrooms, a second language teaching environment and group-oriented teaching. SFA systems were installed in a grade two classroom (ages 7-8), a grade three classroom (ages 8-9) and a secondary classroom (ages 13-17) for three months.

Sound level, speech intelligibility, as well as behavioral measures, along with teacher and student interview data were collected. With the SFA system in place, the SNR in the classrooms improved from approximately +4.8 dB to +10.2 dB. There were significant mean differences between the amplified and un-amplified conditions in speech intelligibility scores, as measured by the number of errors made for the 42 Inuttitut syllables. Children with and without hearing loss benefited from the FM system, as measured by speech intelligibility and percentage of time spent doing on-task behavior. Children with hearing loss still made significantly more errors than did their normal hearing counterparts, but made greater average improvements in speech intelligibility with the SFA system turned on.

The behavioral observation measures recorded by the researchers, which included watching the teacher, body orientation, movement and talk, were all influenced significantly in the positive direction by the FM system. Teachers reported many positive changes in their students, such as increased attention and better listening skills. Teachers also noted that they themselves experienced less vocal fatigue. The authors concluded that the Sound Field FM system was very successful in improving the classroom hearing environment despite the obstacles described above.

SFA systems have been compared to other amplification technologies, such as FM systems linked to hearing aids and desktop personal FM systems. When linked to hearing aids, FM systems provide a direct feed from the teacher's microphone to the child's ear. A desktop system involves placing a wireless speaker system on the child's desk and projecting the teacher's voice through it.

Anderson and Goldstein (2004) compared the speech perception benefits of wall mounted SFA systems for children with hearing aids with two other amplification technologies that are currently used in many classrooms. These were FM systems linked to personal hearing aids and desktop personal sound field FM systems. This study used a small N alternating treatments design. The eight participants, aged 9-12, were randomly assigned to treatment order and repeated Hearing in Noise Test (HINT) sentence lists under four conditions: using hearing aids alone, and using hearing aids in combination with each of the three SNR amplification devices. The Sound Field system in combination with the children's hearing aids did not provide any additional benefit on the HINT test compared to the hearing aid alone. However, both the desktop and the personal FM systems used in combination with the children's hearing aids were shown to significantly improve test scores on the HINT test. The authors noted that the results of the classroom Sound Field system may have been affected by the Reverberation time (RT), which was quite high and which was above recommended levels in the classroom where testing took place. Because of the small sample size (eight children), it may not be appropriate to generalize the results of this study; however, the authors agree that because their findings were "robust and consistent" (Anderson & Goldstein, 2004, p. 9), they may generalize to similar individuals.

As in the Anderson and Goldstein (2004) study, Iglehart (2004) compared speech perception benefits under differing conditions. He compared speech perception scores obtained while using a wall mounted SFA system, or a desktop SFA system or with no system. However, unlike Anderson and Goldstein, Iglehart studied school-aged children with cochlear implants, rather than children with hearing aids. This study also differed in that testing was conducted in two classroom conditions. With the SFA system turned on, one classroom was noisy, with a background noise of 55 dBA, a SNR of +5 dB, and a RT of 0.94 seconds. The other classroom was quiet, with a background noise of 33 dBA, a SNR of +18 and a RT of 0.30 seconds. The two levels of classroom acoustics were counterbalanced and the order of sound field application was varied among participants.

Iglehart measured the number of correctly recognized phonemes using recorded isophonemic lists of consonant-vowel-consonant (CVC) words on compact disk. The sound field wall-mounted system and the desktop system were shown to provide significant benefit to students with cochlear implants. No significant difference was found between the two systems under the quiet condition; however, the desktop system was shown to provide a greater benefit than the wall-mounted system in the acoustically poor classroom. This may be because it is closer to the student and therefore does not produce the same RT increase as the wall mounted system that is located farther away from the student. Also, in contrast to Anderson and Goldstein, Iglehart found a benefit from the sound field wall mounted system in both classrooms. Iglehart also notes that neither system adequately made up for the poor acoustics in the classroom and although they both help, it is still necessary to make changes in the classroom in order to improve acoustics to a sufficient level.

University and College classrooms also provide potential candidates for SFA benefits. These environments often contain large numbers of students in large reverberant classrooms, where the primary teaching route is through audition. SFA may improve the environment making teaching more effective. Some evidence for this has been provided by Woodford, Prichard, and Jones (1999), who studied classroom acoustics and SFA in seven classrooms in five universities. Sound levels were measured and found to be an average of 43.5 dBA, 13.5 dB above the recommended levels of 30 dBA.

Data on sound level were not collected during the amplification condition and no data on RT or SNR were provided for this study. A total of 383 undergraduate students and their teachers filled out a pre- and post-amplification questionnaire. On the pre-amplification questionnaire, seventy-five percent of students indicated that they had encountered problems understanding what their teacher was saying in the past. On the post-amplification questionnaire, both students and teachers responded that they had positive experiences with classroom amplification. They indicated that an improvement in listening conditions was apparent with classroom amplification. Teachers were able to increase their volume without projecting as much while using the SFA system.

When taken together, these studies tentatively support the argument that the SFA technology is effective under some conditions for students with and without hearing impairment. High levels of background noise, low SNR and high RT are common complaints in classrooms and may be hindering the educational potential of millions of children. Some populations are more sensitive to poor acoustical conditions in the classroom and therefore may require optimal conditions in order to succeed. Research has indicated that children with hearing loss and ESL students fit into this category and may therefore benefit significantly from SFA systems.

SFA technology successfully improves the SNR in the classroom and as a result the learning environment becomes more conducive to speech perception for both hearing impaired and normal hearing children and adults. Behavioral measures and teacher questionnaires indicate that SFA technology has also been shown to improve attention, focus and listening behavior in the classroom. Some conflicting results indicate that Sound Field technology did not make an improvement in test scores over hearing aids alone (for the hearing impaired) but these results may be due to inadequate testing conditions, including a RT that is much higher than is recommended (Anderson & Goldstein, 2004). This issue may be addressed in future research. Also, because a head start was noted for children who were exposed to the technology, but then lost by the end of the study (Mendel et al., 2003), more sensitive measures assessing multiple sources of improvement may clarify the benefits of SFA technology in long-term use. The results of Crandell and Smaldino (1996) and Eriks-Brophy and Ayukawa (2000), which address the special circumstances of second language learning, suggest the need for future research that examines the benefits of using Sound Field technology to aid in speech perception in second language learning classrooms.

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Benefits of Sound Field Amplification on speech perception and classroom behavior in the second language learning classroom

Lindsay Page

March 30, 2007

Abstract

Results of many studies of Sound Field Amplification (SFA) have shown a positive effect of SFA on both speech perception and classroom behavior in mainstream classrooms; however, to date, there have been few studies assessing SFA for second language learning (L2) classrooms. The present study assessed the impact of SFA on speech perception and classroom behavior in a grade four French immersion classroom. A single-subject small N repeated-measures design was used. Background noise was presented at 60 dBA, a level typically found in classrooms. The SFA system was preset to deliver a gain of 15 dB. Speech perception was measured with a dictation test of phonetically-balanced French words presented both in a list and embedded in sentences. Students were instructed to write down the words and sentences. Results are discussed in relation to the use of SFA as a cost effective educational tool to improve language perception and classroom behavior.

Classrooms are primarily auditory learning environments. Students of all ages from kindergarten to university must learn to accurately decode and organize the speech signal conveyed by the teacher. However, compared to adults, children require a sharper auditory signal. Because of their under-developed neurological network and lack of listening and life experience, children are not as proficient as adults at performing the automatic filling in of the gaps of missed information. Therefore, children require a quieter environment and a louder speech signal in order to process an auditory signal (Flexer & Long, 2003).

Some children may be facing greater challenges than others. For example, children learning a second language (L2) are at an increased risk for speech perception errors. Children learning a second language have less experience in the language of instruction than children learning in their first language, therefore they are at an even larger disadvantage to fill in the gaps of missed information. This suggests that it would be beneficial to provide L2 children optimal access to a high quality acoustical signal and there is support for this suggestion. Crandell (1996) found that L2 children require a quieter environment and louder signal in order to perform as well as their first language learning (L1) counterparts on tests of speech perception. The topic of second language speech perception will be discussed after a general introduction to past research on acoustics in the mainstream classroom is discussed.

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Because the above-mentioned speech recognition obstacles are found widely in classrooms, technology that improves the classroom acoustical environment may provide benefits for students' speech perception and possibly their language and literacy skills. One way to improve the auditory signal in classrooms is through the Sound Field Amplification system (SFA), a form of amplification technology that has been shown to improve the signal to noise ratio (SNR) that is often too low in classrooms. The teacher wears a microphone that is placed 4-6 inches from the teacher's mouth. It projects her voice from audio speakers that are strategically placed throughout the classroom. The result is that everyone in all locations of the classroom has access to a higher quality acoustical signal. In essence, it makes the teacher's voice stand out more than the background noise originating from inside and outside the classroom. This type of system provides the benefits of optimal access to verbal instruction for children and adults with and without hearing loss.

Results of many studies of SFA in the mainstream classroom have shown a positive effect of SFA on speech perception (Anderson & Goldstein, 2004; Eriks-Brophy,

& Ayukawa, 2000, Mendel, Roberts, & Walton, 2003) and classroom behavior (Eriks-Brophy, & Ayukawa, 2000; Palmer, 1998; Rosenberg, Blake-Rahtner, Heavner, Allen, Redmond, & Phillips, 1995). To date, there have been few studies assessing SFA for L2 classrooms. Eriks-Brophy and Ayukawa (2000), and Crandell (1996) studied SFA in the second language environment and reported a benefit of SFA in the second language classroom, but they stressed that more research is needed in this area in order to provide increased support for the use of SFA as an educational tool.

When compared to adults, children are not as proficient at filling in the gaps of missed information. This may be due to a lack of life experience as well as a lack of language experience: so children don't have as much general knowledge as well as language specific knowledge to fill in the gaps. It may also be true that children learning a second language are at an increased disadvantage when it comes to filling in the gaps because of their unfamiliarity with the sounds and words common to the second language. With a lack of experience they may be less able to use context and knowledge of the sound system to guide the filling in of missed information. The present study uses speech perception, along with behavioral measures to assess the potential benefits of SFA in the special case of the second language learning environment. A single-subjects repeated-measures design was used.

Method

Participants

Twenty-three grade four students at Rosedale French Immersion Public School in the Algoma District School Board were selected to participate in the study.

Materials and Apparatus

A CD player presented background noise at a level of 60dBA. Background noise consisted of a recording of cafeteria noise (freesoundproject.org). Another CD player presented dictation stimuli at a level of 75dBA. The dictations consisted of a random sample of phonetically balanced French words and words embedded within the context of sentences that were familiar to the children. During the amplified treatment condition, the Sound Field Amplification system was turned on. It consisted of a wireless microphone and 4 speakers placed on each of four walls.

Procedures

Children participated in four dictation sessions in L2 (French) under two conditions: with amplification and without amplification. Dictations started with a baseline condition (no amplification), then treatment (with amplification) followed by another treatment (with amplification) and finally, a return to baseline (no amplification). The lesson before each treatment condition was amplified and the lesson before each baseline condition was un-amplified so as to avoid a novelty effect of amplification during the dictation. Words, in addition to key words embedded within the context of sentences were used to measure the effect of context on speech perception. When key words are presented within sentences, the effect of the context may aid the child in filling in the blanks of missed information. So, this added measure allows us to see whether simply studying the speech perception of words as an indication of the benefits of SFA is misleading because in the mainstream classroom, information is provided in the context of sentences. Although the child may have missed certain aspects of the speech message, by the time the end of the sentence is reached, he/she may have been able to fill in the blanks well enough to extract the necessary information. However, even if this is the case, a benefit may still be found in improving the SNR. Less effort may be expended on trying to figure out what was said, and more effort can be spent understanding the material being taught.

The words and sentences were recorded on CD by a fluent speaker of French and were presented via CD player at a level of 75 dBA, as measured by a Galaxy Audio brand, Check Mate sound pressure level meter, model CM 140. The CD player was placed at the front of the classroom, four inches away from the SFA microphone. The microphone was in place regardless of condition. During the dictation, a CD of cafeteria noise was also presented as background noise at a level of 60 dBA, a level typically found in classrooms (Crandell & Smaldino, 2000). The SFA system was preset to deliver a gain of 15 dB.

Students were instructed to write down the words and sentences that they heard. A total of 40 words and 20 sentences were dictated. Results of the dictation were scored as correct or incorrect. Spelling mistakes consistent with correct phonetic pronunciation were scored as correct. Other mistakes were scored as incorrect.

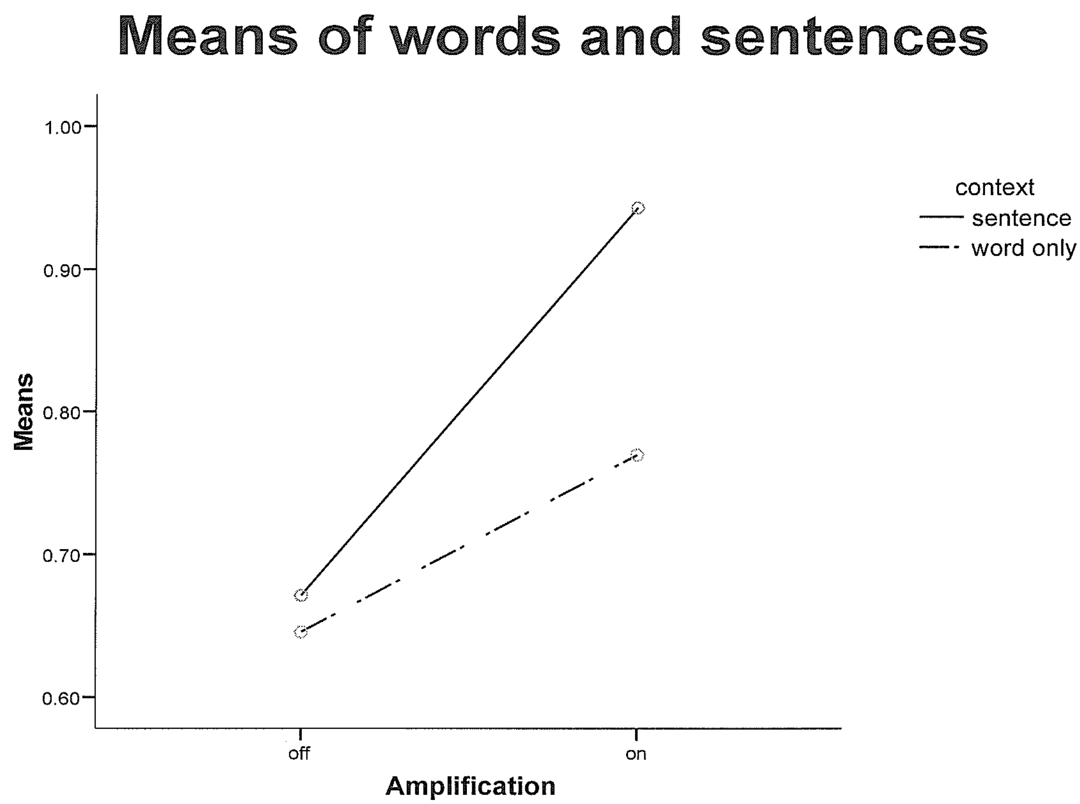
On a separate occasion, a random sample of behavior from five children (selected because of their frequent off-task behavior, as noted by the teacher was recorded by the researcher. These students were selected in order to more easily measure differences in behavior during the two amplification conditions. Behavior was measured during four separate lessons of ten minutes each, two with amplification and two without, using eco-behavioral computer software created for the purposes of this experiment. As in the dictation task, amplification was the same in the lesson prior to the behavioral measure to avoid a novelty effect. During random time intervals of between thirty seconds and one minute, the researcher was prompted by the computer program to record the behavior of the five children according to variables demonstrating on or off task behavior.

The teacher also filled out a questionnaire assessing her feelings towards the amplification system using an open-ended questionnaire in addition to a seven-point Likert scale. Several variables such as perceived voice strain, classroom behavior and management, ease of use of equipment, etc. were used to assess the teacher's attitudes towards SFA.

Parents of all students in the study provided informed consent and the students provided assent. There was minimal risk associated with participation in this study and participants were thoroughly debriefed following their participation on the purpose and expected outcome of the study.

Results

An analysis of variance of the results of the speech perception measure indicate a main effect of amplification $F\,(1, 90)=120.875$, $p=.000$. As expected, a greater difference was found between amplification versus no amplification for the words embedded within the context of sentences $F\,(1, 90)=16.874$, $p=.000$, see figure 1. There was also a significant interaction between subjects and amplification $F\,(22, 90)=1.811$, $p=.027$. Results of the behavioral measures were not statistically significant $F(1, 9)=1.160$, $p=.309$. On the teacher questionnaire, the teacher reported better classroom focus and control during amplification in the open ended section and provided answers consistent with a positive attitude towards amplification on the Likert scaled questions.



[Figure 1 Means of words and words embedded within the context of a sentence]

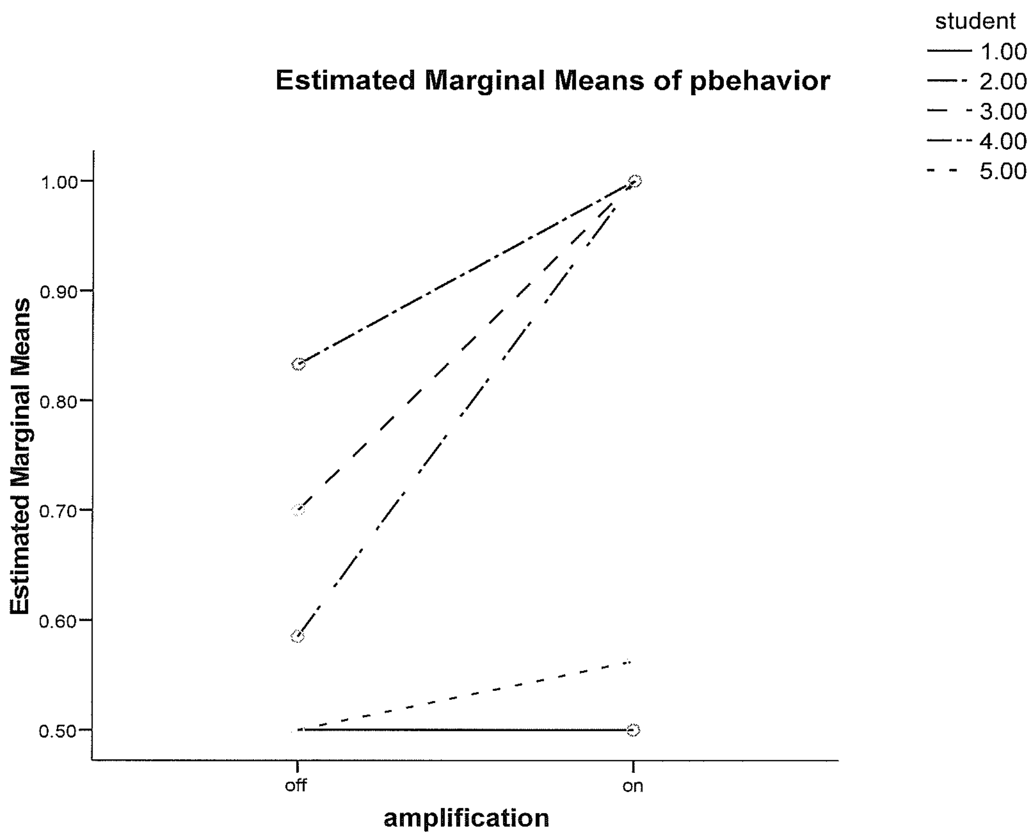
Discussion

The present investigation examined the effectiveness of Sound Field amplification on measures of speech perception and classroom behavior in a second language classroom. An analysis of the speech perception data shows evidence in line with previous research supporting the use of SFA in the classroom. In this case, the use of SFA in the classroom has been shown to improve speech perception for students in a second language environment. When taken with the results of past research on second language learning and their need for a higher quality speech signal, the argument for the use of SFA in the mainstream classroom is well supported.

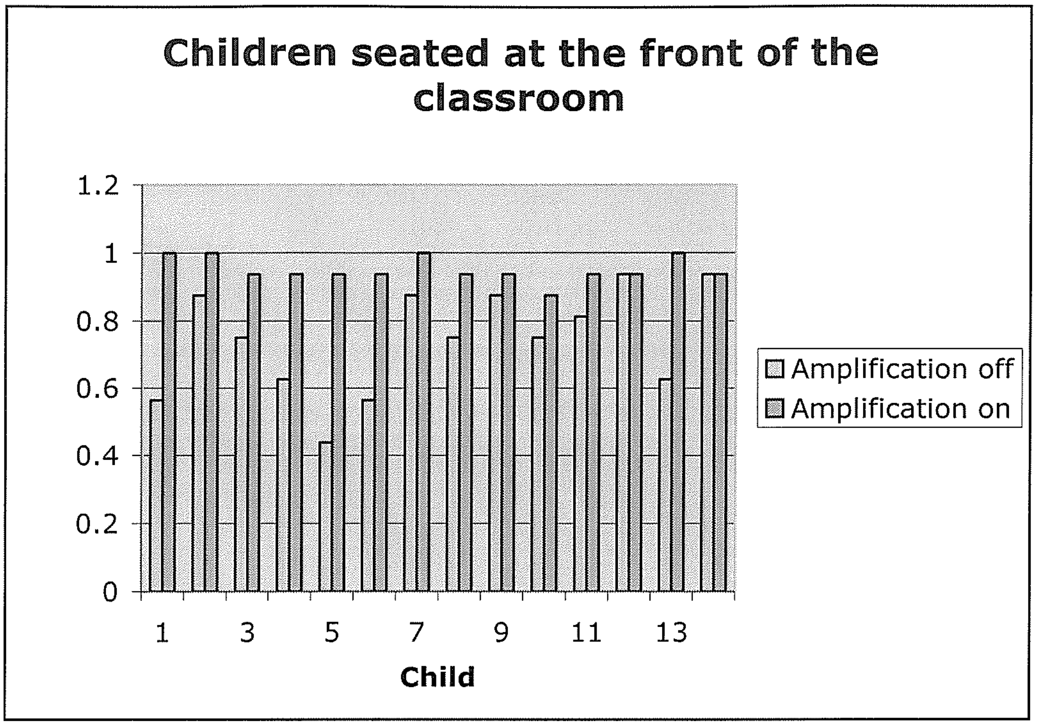
The greatest benefit of amplification was found in the interacting conditions of words presented within the context of a sentence paired with the amplification turned on. As mentioned previously, this condition was included to more accurately reflect the classroom environment. Since teachers communicate through language within the context of sentences, it makes sense to study the effectiveness of an educational tool like SFA under these more realistic conditions. The results of this manipulation suggest that when the acoustic conditions are poor, it does not matter if the teacher provides the context, the children can't decipher the message regardless of whether the context was provided or not. However, when the amplification was turned on, the scores for the words that were presented within the context of a sentence was almost perfect. This suggests that under realistic classroom conditions, amplification is successful at improving speech perception. The interaction between amplification and subject suggests that different children reacted differently to amplification. This may be because the children seated at the back of the classroom responded differently than the children seated at the front of the classroom. Figures 3 and 4 illustrate that the children who were seated at the back of the classroom displayed more variability in mean scores between the conditions of amplification off and amplification on. Because these children were at a disadvantage when the amplification was turned off, a greater increase in mean score was expected from them when the amplification was turned on. This is because in this condition, all the students had equal access to the message regardless of classroom position.

The present study failed to replicate previous research that found a behavioral benefit of SFA. There are a few explanations for this finding. First, the students were unusually quiet during the lessons that were observed. This means there was not much background noise present to interfere with the teacher's speech. Therefore, children that are more prone to off-task behavior when the classroom acoustic environment is poor and noisy may have stayed on task because there were no significant barriers to hearing the teacher. If this is the case, it may be beneficial for future studies on this topic to present a constant and measurable level of background noise for this part of the study in order to more accurately represent the natural classroom environment. Another factor that may have contributed to the lack of significance of this result was that the lessons observed were only ten minutes in length and may not have been long enough to obtain a reasonable sample size of data entries of behavior to see a measurable difference between amplification and no amplification. Future studies may address this by using longer lessons and more frequent data entries. Also, although the results of the behavioral measure were not statistically significant, figure 2 illustrates that the variability when the amplification was off is my higher than when its on for most students. Due to the small sample size it is difficult to make a definitive conclusion.

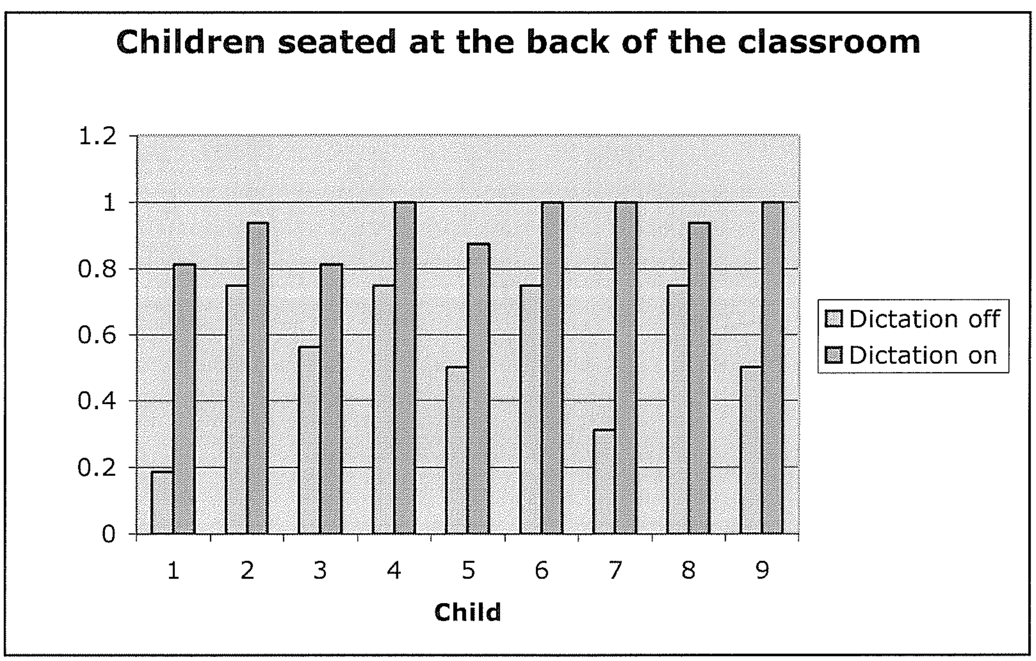
Second language learners are at a disadvantage in terms of their knowledge of the second language. When background noise or a poor SNR contribute to masking the spoken message, relying on their knowledge of the language in order to fill in the gaps of missed information may be a difficult and unreasonable demand for second language learners. The result may be unintelligible or misunderstood sounds, words or phrases. The present study concludes that SFA significantly improves speech perception for children learning a second language. The use of SFA may lead to students more accurately decoding the speech message and spending less time trying to figure out what the teacher said and more time learning the material being taught. School administrators as well as policy makers should therefore consider the installation and use of SFA for present and future second language as well as mainstream classrooms.



[Figure 2: Classroom behavior data]



[Figure 3: Behavior data for children seated at the front of the classroom]



[Figure 4: Behavior data for children seated at the back of the classroom]

Appendix A: Teacher Questionnaire

Part 1

Please explain any benefits and drawbacks you have experienced in your classroom because of Sound Field Amplification.

Part 2

Please fill in the following questionnaire where 1=Strongly Disagree and 7=Strongly Agree

1. I would like to keep the amplification equipment in my classroom permanently.

1 2 3 4 5 6 7

2. The amplification equipment was easy to use.

1 2 3 4 5 6 7

3. Amplification equipment has decreased the listening skills of the children in my class.

1 2 3 4 5 6 7

4. When the amplification system is turned on, the students seem to be more engaged.

1 2 3 4 5 6 7

5. The children in my classroom do not like the amplification equipment.

1 2 3 4 5 6 7

6. When the amplification is turned on, I don't have to repeat myself as often.

1 2 3 4 5 6 7

7. My students notice when the amplification is turned off.

1 2 3 4 5 6 7

8. I'm not comfortable using amplification the classroom.

1 2 3 4 5 6 7

9. I would recommend amplification technology for use in other classrooms.

1 2 3 4 5 6 7

10. Using amplification equipment has decreased participation in my classroom.

1 2 3 4 5 6 7

11. Using amplification equipment decreased how tired I felt at the end of the day.

1 2 3 4 5 6 7

12. The amplification has increased or enhanced my use of other audio-visual equipment in the classroom.

1 2 3 4 5 6 7

13. I have less control over my class when the amplification equipment is used.

1 2 3 4 5 6 7

Appendix B: Letter to parents

Dear Parents/Guardians, February 21, 2007

My name is Lindsay Page and I'm a fourth year Honours Psychology student at Algoma University. In my thesis project, I am exploring the topic of second language learning and in order to complete this research, I am seeking the participation of your child/ren.

If your child participates he/she will complete four grade appropriate dictation sessions under conditions in which the relative amount of background noise varies. These dictation sessions will take place during the school day, each lasting about five minutes. I will be debriefing the children on the purpose and expected results of the study at the end of the dictations.

Participation in this study is voluntary and your child may decline to participate at any time before or during the study. The children participating in the study will not be identified by name. As a thank you for participating, the children will also be placed in a draw for Galaxy cinema tickets. Please feel free to contact me at lpage@students.auc.ca with any questions.

Thank You,
Sincerely,

Lindsay Page

Please detach and return the bottom portion to Mlle TenBrinke by Wednesday February 28, 2007.

____
Child's name

[ ] may

[ ] may not

Participate in four dictation sessions for the purpose of research on second language learning.

____________________ __________________
Parent/Guardian's Signature Date

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