Development of Selective Auditory Attention: Effects of the Meaning of Competing Speech and Daily Exposure to Soundfield Amplification

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In Study One, children's selective auditory attention was assessed to determine effects of meaning of competing speech and daily exposure to soundfield amplification. Subjects included 70 normal-hearing first grade children whose primary language was English. Four first grade classrooms received soundfield amplification systems (SF group), and four classrooms served as controls (No SF group). Word recognition testing was performed using target English words presented with competing speech spoken in English and French. All testing was administered without soundfield amplification at the beginning and end of the four month study. The SF and No SF groups improved significantly over time in the English and French competing conditions. No significant difference was seen between mean scores for the two groups in the English competing condition. A borderline significant (p = 0.053) effect of soundfield amplification was seen for the French competing condition, indicating a possible positive effect of daily exposure to soundfield amplification on children's abilities to ignore competing speech that lacks meaning. Study Two was a pilot study in which results from Study One were reanalyzed to investigate possible differential effects of daily exposure to soundfield amplification on development of selective auditory attention in students from different ethnic backgrounds. Results revealed a significant positive effect of soundfield amplification for the English and French competing conditions in classrooms where students were predominately Hispanic, but not for classrooms in which students were predominately African American. Implications for future research are discussed.

Introduction

In a typical classroom, learning depends heavily on students' abilities to hear and understand information presented by the teacher in the form of spoken language. This is particularly true in early elementary grades where almost all classroom instruction involves auditory-verbal exchange between the teacher and the students (Picard & Bradley, 2001). Accurate speech perception is particularly important as children work to develop pre-literacy and early literacy skills that rely on accurate perception and manipulation of individual speech sounds (e.g., phonological awareness and spelling). To develop these skills, children must have adequate selective auditory attention abilities in order to focus attention on the target speech signal (i.e., the teacher's voice) while ignoring irrelevant competing sounds often present in the classroom environment.

Classroom Acoustics

Unfortunately, many classrooms are characterized by poor acoustical conditions which can interfere with young students' abilities to attend to and accurately perceive what the teacher is saying (e.g., Bess, Sinclair, & Riggs, 1984; Bradley; 1986; Eriks-Brophy & Ayukawa, 2000; Knecht, Nelson, Whitelaw, & Feth, 2002; Palmer, 1998; Picard & Bradley, 2001; Rosenberg, 1998; Rosenberg et al., 1999). In early elementary grades, background noise and competing speech are common problems due to the active nature of the learning environment. Background noise impedes accurate speech perception by masking portions of the target auditory signal due to spectral overlap between the masking noise and the target speech (i.e., energetic masking) (Crandell & Smaldino, 2000). In addition, speech from one or more competing (or masking) talkers may decrease speech perception due to informational masking, which is a type of interference that can affect a listener's ability to (1) segregate simultaneous speech signals, (2) selectively focus attention only on the words spoken by the target talker, and (3) accurately process the components of the target speech signal (Cooke, Garcia Lecumberri, & Barker, 2008).

Previous studies have shown that the presence of competing noise or competing speech decreases speech recognition for children with hearing loss (e.g., Crandell, 1993; Finitzo-Hieber & Tillman, 1978) and children with normal hearing (e.g., Crandell & Smaldino, 1996; Elliott, 1979; Elliott et al., 1979; Finitzo-Hieber & Tillman, 1978; Papso & Blood, 1989). To maximize speech understanding in classrooms, the American Speech-Language-Hearing Association (ASHA, 2005) and the American National Standards Institute (ANSI, 2002) have proposed criteria for classroom acoustical conditions. Both organizations recommend that unoccupied classroom noise levels not exceed 35 dBA and that classroom signal-to-noise ratios (SNRs) equal or exceed +15 dB. However, many studies have found that typical classrooms often fail to meet these standards (e.g., Eriks-Brophy & Ayukawa, 2000; Knecht et al., 2002; Larsen & Blair, 2008; Palmer, 1998; Picard & Bradley, 2001; Rosenberg, 1998; Rosenberg et al., 1999).

Selective Auditory Attention

The presence of classroom noise and competing speech is of particular concern in early elementary grades because young children do not have mature selective auditory attention skills. Numerous studies have shown that children with normal hearing experience greater difficulties than adults in understanding speech in poor acoustical conditions (e.g., Johnson, 2000; Klatte, Lachmann, & Meis, 2010; Nábělek & Robinson, 1982; Neuman & Hochberg, 1983; Neuman, Wroblewski, Hajicek, & Rubinstein, 2010). Evidence from different age groups suggests children's abilities to accurately perceive consonant sounds and target sentences in background noise do not reach adult-like levels until the teenage years (e.g., Johnson, 2000; Neuman & Hochberg, 1983; Stuart, 2008). A similar pattern of results has been reported in competing speech conditions, with children's syntactic comprehension for target sentences not reaching adult levels of accuracy until 11 or 12 years of age (Leech, Aydelott, Symons, Carnevale, & Dick, 2007). As such, even when hearing is normal, young children are at a disadvantage compared to older children and adults when faced with the challenge of understanding speech in conditions where background noise and/or competing speech is present.

Although children's selective auditory attention improves with age, performance on a particular task can differ depending on characteristics of the competing auditory signals. For example, Papso and Blood (1989) compared word recognition performance of 4- and 5-year-old children in 20-talker multi-talker babble and pink noise. Their results indicated significantly poorer performance in the multi-talker babble condition. Similarly, Cherry and Kruger (1983) found that 7- to 9-year-old children experienced significantly greater difficulties selectively attending to monosyllabic words when the competing signal was meaningful speech (i.e., a background story read by a single talker) as compared to white noise or reversed speech. Together, these results appear to indicate that children's difficulties with selective auditory attention increase as similarities increase between the target speech signal and the competing auditory signal(s). Therefore, ignoring speech from other students in the classroom may be more difficult for children than ignoring non-speech noise, such as noise from an overhead projector.

Given the nature of the learning environment, competing speech conditions are relatively common in classrooms for young children. As such, a question of interest relates to how characteristics of competing speech signals affect children's selective auditory attention performance. Numerous studies have documented that adult listeners' performance is affected by non-linguistic characteristics, such as the intensity (e.g., Cooke, Garcia Lecumberri, & Barker, 2008), number (e.g., Simpson & Cooke, 2005), gender (e.g., Brungart, 2001), and spatial location (e.g., Freyman, Balakrishnan, & Helfer, 2004) of the competing talkers. In contrast, a very small number of studies have investigated effects of linguistic characteristics of competing speech on children's selective auditory attention performance. For example, Cherry and Kruger (1983) found that 7- to 9-year-old children experienced significantly greater difficulties ignoring meaningful, forward speech as compared to reversed speech. Alone, these results appear to indicate that meaningful competing speech is a more effective masker than competing speech that lacks meaning. However, Chermak and Zielonko (1977) found no significant differences in word recognition performance of 9- to 10-year-old children when the competing signal consisted of grammatical speech (i.e., meaningful speech that followed syntactic rules), semantically anomalous strings (i.e., non-meaningful speech that followed syntactic rules), or ungrammatical strings (i.e., non-meaningful speech that violated syntactic rules).

There are a number of possible explanations for the inconsistencies between results reported by these two studies. First, the studies included children from different age groups. Therefore, the effect of linguistic content of competing speech may have been impacted by the children's development. Second, the SNR differed between the two studies, with a 0 dB SNR used by Cherry and Kruger (1983) and a +8 dB SNR used by Chermak and Zielonko (1977). As such, the different patterns of results may indicate that effects of linguistic characteristics of competing speech vary as a function of the SNR. In addition, results of the two studies may have been affected by differences between the signals used to represent "non-meaningful" speech. Cherry and Kruger (1983) used reversed speech; whereas, Chermak and Zielonko (1977) used semantically anomalous strings (i.e., followed syntactic rules) and ungrammatical strings (i.e., did not follow syntactic rules) of words. Although these signals each lack meaning at the sentence level, other characteristics of the signals may have influenced the listeners' performance. For example, reversed speech is devoid of meaning; however, reversal of speech changes the temporal envelope such that the rapid onsets and slow offsets typical of plosive consonants in forward speech become slow onsets and rapid offsets (Rhebergen, Versfeld, & Dreschler, 2005). In contrast, the competing speech used by Chermak and Zielonko (1977) was not completely devoid of meaning. Although the words in this study did not combine to express meaning at the sentence level, the individual words still carried their own meaning.

To avoid the disadvantages of reversed speech and semantically anomalous sentences, a small number of studies have used competing speech spoken in two or more languages to assess selective auditory attention in adult listeners (e.g., Freyman, Balakrishnan, & Helfer, 2001; Garcia, Lecumberri & Cooke, 2006; Reel & Hicks, in press; Tun, O'Kane, & Wingfield, 2002; Van Engen & Bradlow, 2007). Speech in an unfamiliar language provides a masking signal that has the same basic time envelope as speech in the native language (i.e., with rapid onsets and slow offsets) but is lacking in semantic content, both at the sentence and word level. Therefore, use of speech in an unfamiliar language may provide a better control condition than nonsense sentences or reversed speech when testing effects of the meaning of competing speech. Despite these advantages, there is currently a lack of studies using competing speech in different languages to evaluate selective auditory attention in children. Therefore, the current study addressed this gap in previous research by investigating first grade children's selective attention in conditions where competing speech was spoken in English or French.

Soundfield Amplification

Given poor acoustic conditions in typical classrooms and immature selective auditory attention abilities in children, it is important to implement strategies to improve the classroom learning environment. Use of a soundfield amplification system may help overcome negative effects of poor classroom acoustics, thus potentially improving students' learning in areas that rely heavily on accurate speech perception (e.g., phonological awareness, spelling). Such systems typically consist of a microphone and transmitter worn by the teacher, an amplifier/receiver, and one to five loudspeakers located around the classroom (Flexer, 1995). The primary goal is to improve the SNR by positioning the microphone within 3 to 4 inches of the teacher's mouth (Sapienza, Crandell, & Curtis, 1999). At this location, the intensity of the target speech signal is greater than the surrounding noise. This optimal SNR is then delivered through speakers "so that students in the back of the classroom can hear the teacher's voice as clearly and precisely as students seated near the teacher" (Rosenberg & Blake-Rahter, 1995, p. 167).

Previous studies have investigated effects of classroom soundfield amplification on various populations of children, including those with hearing loss, normal hearing, learning disabilities, and English as a second language. Teachers' responses have revealed benefits such as increased student attention (Eriks-Brophy & Ayukawa, 2000; McSporran & Butterworth, 1997; Rosenberg et al., 1999), increased classroom control (Palmer, 1998), and reduced teacher fatigue/vocal problems (Eriks-Brophy & Ayukawa, 2000; Rosenberg et al., 1999). Although useful, these subjective findings must be interpreted with some caution due to the potential for examiner bias in judging/rating students' performance. However, studies using objective measures (e.g., video recording, in-classroom observation, analysis of test scores, etc.) have also reported significant benefits of soundfield amplification. For example, when testing is conducted with a soundfield system in use, investigations of normal hearing children have shown immediate improvements in speech intelligibility (Eriks-Brophy & Ayukawa, 2000; Flexer, Millin, & Brown, 1990), spelling performance (Zabel & Tabor, 1993), classroom behavior (Eriks-Brophy & Ayukawa, 2000; Palmer, 1998), and the amount of managerial time necessary at the beginning of class (Ryan, 2009).

Although positive immediate effects of soundfield amplification are well documented, questions remain regarding how daily exposure to soundfield amplification may affect children's development over time. By comparing pre- and post-testing administered without use of soundfield amplification, studies have noted significantly greater improvements in reading related skills (Darai, 2000), language arts, and composite achievement test scores for children in classrooms with soundfield amplification as compared to control classrooms without amplification (Sarf as cited in Rosenberg & Blake-Rahter, 1995). However, other studies have failed to find significant improvements for students exposed daily to soundfield amplification. For example, Purcell and Millet (2010) compared first grade students in amplified and unamplified classrooms and found no significant difference between the percentage of students in each group who were reading at grade level by the end of the school year.

Given that the primary purpose of soundfield amplification is to improve children's abilities to perceive the teacher's voice in noisy classroom conditions, a logical question relates to whether daily exposure to soundfield amplification impacts development of selective auditory attention over time. More specifically, would such exposure enhance children's abilities to focus attention on the target signal and ignore competing signals, even in conditions where soundfield amplification is not used? In contrast, would daily exposure to an amplified signal serve as a "crutch" that could hinder normal development of selective auditory attention? Or would daily use of classroom soundfield amplification improve children's selective auditory attention when the system is in use but neither enhance nor hinder overall development of such skills (i.e., performance in unamplified environments)?

Only one published study could be located which attempted to answer these questions by longitudinally measuring effects of soundfield amplification on children's selective auditory attention skills. Mendel, Roberts, and Walton (2003) assessed normal hearing children in classrooms with (i.e., experimental) and without (i.e., control) soundfield amplification over the kindergarten and first grade years. The experimental group performed significantly better than the control group when testing was administered through the soundfield system for the experimental group and without the soundfield system for the control group. Over time, both groups improved significantly in their ability to perceive speech in prerecorded classroom-type noise. However, no significant differences were noted between performance of the experimental and control group when tested without the use of soundfield amplification. These results suggest no significant effect of daily soundfield amplification exposure on children's development of speech understanding in classroom-type noise. Therefore, daily exposure to soundfield amplification neither hindered nor enhanced actual development of selective auditory attention, but use of the system did lead to immediate improvements in the children's abilities to understand speech in the presence of background noise. Although these findings provide important preliminary evidence, additional research is needed to determine if such results can be replicated under other conditions, including other groups of listeners and other types of competing auditory signals.

Study One

Although previous studies have demonstrated various benefits of soundfield amplification, there is a paucity of research using objective measures to evaluate how daily exposure to soundfield amplification affects children's development of selective auditory attention skills over time. As such, Study One compared selective auditory attention development of two groups of first grade students: those exposed to soundfield amplification on a daily basis (i.e., experimental or SF group) and those in classrooms without soundfield amplification (i.e., control or No SF group). The primary goals of the study involved using objective measures to investigate the following areas:

- Development of selective auditory attention skills in normal hearing first grade students,
- Effects of meaning of competing speech on selective auditory attention performance, and
- Effects of daily use of classroom soundfield amplification on students' development of selective auditory attentions skills.

Method

Schools, classrooms, and subjects. Three elementary schools in Lubbock, Texas, participated in the study during the second semester of the school year. Each school qualified for Title I funds, an indicator of the student population's low socioeconomic status (SES). From these schools, eight regular education first grade classrooms took part in the study, including four classrooms at School A, two classrooms at School B, and two classrooms at School C. As compensation for their assistance, each participating classroom was given a total of $40.00 in gift certificates. All research procedures were approved by an institutional review board.

All participating schools required every first grade classroom to strictly follow the curriculum of the Voyager Universal Literacy System (2003). The structured nature of the Voyager program reduced possible effects of variability between the literacy instruction provided in the eight classrooms. Each school administered Voyager benchmark testing on three dates during the school year to assess the students' reading skills. Scores from the first benchmark test were used to ensure that the students' baseline reading skills were similar among the eight classrooms.

Half of the participating classrooms at each school were randomly chosen to be in the experimental (SF) group, and the remaining four classrooms served as controls (No SF). In the four experimental classrooms, a Phonic Ear Easy Listener Soundfield Amplification System was installed and used during the second semester of the school year. Each system included four soundfield speakers, a receiver, and a transmitter/boom microphone worn by the teacher. Teachers were instructed to use the system every day during any group instruction time. The volume and tone controls on each receiver were set to the highest levels that could be attained without creating feedback or other interference. During periodic visits to each classroom, the soundfield receivers were monitored to ensure that the controls had not been adjusted from their original positions.

Consents were obtained from 99 first grade students, with 49 students in the experimental (SF) group and 50 in the control (No SF) group. As per teacher report, all participants spoke English as their primary language and had no known significant hearing loss. When analyzing the results, scores were excluded for any subjects who were not present at both the pre- and post-testing. Results from 70 students were included in the analyses.

Classroom acoustical measurements. The eight participating classrooms had roughly similar floor plans, including windows along one wall, metal lockers along another wall, a classroom sink, and two bathrooms shared with the adjoining classroom. All classrooms had acoustical ceiling tiles, but flooring materials differed somewhat among the classrooms. The six classrooms at School A and School B were carpeted; whereas, the two School C classrooms had tile flooring. The following acoustical measurements were made in each classroom: unoccupied and occupied ambient noise (dBA), teacher's vocal intensity (dBA), unamplified SNR, and amplified SNR (only in the SF classrooms). Sound level readings were taken from six locations in each classroom, including the four corners, center, and center of the back row (i.e., relative to the typical position where the teacher stood/sat for classroom instruction time). Occupied ambient noise was measured in each classroom while students were engaged in a quiet activity at their desks/tables. Unamplified and amplified measures of each teacher's vocal intensity were performed as the teacher read aloud in an unoccupied classroom. Amplified measurements were taken with the volume control and tone control of the soundfield amplification system set to the positions used daily in each classroom.

Test measures. Selective auditory attention testing was performed at the beginning and end of the four month study. All testing was administered without amplification in order to assess students' skills development, rather than immediate effects of soundfield amplification on performance. Prior to the competing conditions, word recognition testing was administered in quiet to ensure that students could listen for the target word, mark the corresponding picture, and quickly turn the page. For the quiet condition pre- and post-test, subjects listened to one half-list (25 words) from the Auditec compact disc (CD) recording of the Northwestern University Children's Perception of Speech (NU-CHIPS) test (Elliott & Katz, 1980). The NU-CHIPS is a closed-set, picture-pointing word recognition test that consists of monosyllabic words appropriate for receptive language ages of at least 2.6 years. Use of NU-CHIPS half-lists was considered acceptable based on Elliott and Katz' (1980) report that "performance on one half-list will be approximately equivalent to performance on the second half-list" (p. 4).

For the competing conditions, subjects listened to word lists from the Auditec CD recording of the Word Intelligibility by Picture Identification (WIPI) test (Ross & Lerman, 1970) while simultaneously attempting to ignore competing speech from a single talker. The WIPI is a closed-set, picture identification test consisting of four lists of 25 different monosyllabic words found to be appropriate for 5- to 6-year-old children with hearing loss. As such, normal hearing first grade students were expected to have adequate receptive language skills for the WIPI task. When presented in quiet, Ross and Lerman (1970) reported that the four word lists were reliable and essentially equivalent.

WIPI word lists were presented with an English and a French background story to assess effects of the meaning of competing speech on selective auditory attention. The Rainbow Passage (Fairbanks, 1960 as cited in University of Tampere, n.d.), a story containing all normal sounds of the English language, was selected as the meaningful competing speech signal. The non-meaningful competing speech signal was Cendrillon (Perrault, n.d.), a French version of the tale of Cinderella. The French story was considered to be non-meaningful due to the low probability that participating students would have been exposed to the French language. Based on estimates provided by the 2005-2009 American Community Survey, Spanish is spoken by approximately 19% of the population in Lubbock County; whereas, less than 1% of residents speak French (U.S. Census Bureau, 2005-2009).

On the Auditec CD recording of the NU-CHIPS and WIPI word lists, stimulus words were presented by the same male talker. Using Cool Edit Pro Version 2 (2002), the words on each list were normalized for peak intensity (50% of the full scale), and interstimulus pauses were increased to 10 seconds. Both competing stories were read by the same male talker, a native English speaker with language training in French. The stories were recorded with a sampling rate of 44,100 Hz and 16-bit quantization using a Tucker-Davis System II. Each story recording was normalized to be of equal RMS power as computed over the duration of the stimulus. The RMS power of the English story (M = 28.32 dB, SD = 3.03 dB) and the French story (M = 28.72 dB, SD = 8.26 dB) were equivalent.

A different WIPI word list was used for the pre- and post-test administration of each competing story condition. For the English pre-test, four classrooms were randomly selected to receive List 2, and four classrooms were randomly chosen to receive List 3. For the French pre-test, four classrooms were randomly chosen to receive List 1, and the remaining four classrooms were assigned List 4. On the post-test, each classroom received the unused list from the WIPI list/story pairs. The order of testing for the English and French competing conditions was pseudo-randomized to prevent order effects. For the pre-tests, four classrooms were randomly selected to be tested in the English condition first, while the remaining four classrooms were tested in the French condition first. On the post-tests, each classroom was tested in the order opposite of the pre-test order.

The quiet and competing conditions of the selective auditory attention testing were performed in each classroom with the students in their usual seats. The target word lists and competing stories were presented from two portable CD players positioned at the front of the classroom on a plastic stand with two shelves (i.e., one player above the other). The intensity of the word lists and competing stories was measured at 1 meter from the CD players using a sound level meter positioned at the approximate height of the students' ear level. For the quiet condition, the NU-CHIPS words were presented at an intensity of 75 dBA in order to be clearly audible to the students. For the pre- and post-test competing conditions, the WIPI word lists were presented at approximately 73 dBA, and each competing story was presented at approximately 76 dBA. A -3 dB SNR was selected based on results of pilot testing, which suggested that for normal hearing first grade students a 0 dB SNR was too easy; whereas, a – 6 dB SNR was potentially too difficult.

Prior to each test, subjects were given a privacy tri-fold, the appropriate picture booklet, and a writing instrument. The examiner read the test instructions aloud, and during each test, she held the picture booklet at the front of the room to assist students in staying on the target page. Students were instructed to listen to the man on the CD, mark the picture that matched the word he said, and then turn the page as quickly as possible. For the competing conditions, students were instructed to ignore the man reading the story and listen to the man saying, “Show me,” followed by a word matching one of the pictures on the test page. A 3- to 5-second sample of the competing story was presented prior to each test to ensure that the students understood which signal to ignore. During all testing, proctors were positioned throughout the classroom to ensure that students were quiet, did not share answers, and stayed on the correct page or item number. Tests were scored in terms of the percentage of pictures marked correctly.

Results

Classroom acoustics. The mean unoccupied ambient noise level was 37.92 dBA for the SF classrooms and 39.79 dBA for the No SF classrooms. The mean unamplified SNR in the No SF classrooms was 9.45 dBA. In the SF classrooms, the mean SNR was 4.88 dBA in the unamplified condition and 11.38 dBA in the amplified condition, indicating that use of the soundfield amplification system increased the SNR by a mean of 6.5 dBA. Comparison of the acoustical results for each classroom revealed that the mean SNRs in two No SF classrooms ranged from 5 to 5.6 dBA, but the mean SNR in the remaining two No SF classrooms ranged from 12.7 to 14.5 dBA. Therefore, two of the No SF classrooms had unamplified SNRs that were comparable to the mean amplified SNR in the SF classrooms (11.38 dBA). For the SF group, one classroom had a relatively poor SNR in the amplified condition (5.8 dBA), but the amplified SNR in the other three SF classrooms ranged from 12.7 to 13.5 dBA.

Benchmark testing. Voyager benchmark scores were analyzed to determine if the SF and No SF group were similar in their reading skills prior to implementation of the research protocol. A one-way analysis of variance (ANOVA) revealed no significant difference between performance of the SF and No SF classrooms on all subtests. These results show that the SF and No SF group were in fact equivalent in their reading-related skills prior to initiation of the study.

Selective auditory attention. Results for seven classrooms were analyzed, including four SF classrooms and three No SF classrooms. Pre- and post-test scores for one No SF classroom (Classroom F) were excluded from the analyses. Classroom F was the first classroom in which the pre-testing was administered. However, technical errors precluded an accurate representation of the SNR for that classroom. To minimize threats to internal validity, the pre- and post-test selective auditory attention scores for Classroom F were excluded from the data analyses. This resulted in 30 students in the No SF group and 40 students in the SF group.

Quiet. Prior to the competing conditions, NU-CHIPS words were administered in quiet to ensure that students could perform a picture-pointing word recognition task. On the pre-test, the mean percent correct scores were 94.00% (SD = 5.12) for students in SF classrooms and 89.47% (SD = 10.48) for the students in No SF classrooms. Similar scores were seen on the post-test administration of the NU-CHIPS words. The post-test mean percent correct scores were 93.70% (SD = 10.36) for the SF group and 93.73% (SD = 17.35) for the No SF group. Both groups performed well when NU-CHIPS words were presented in quiet, which indicates that the students understood and could perform the task (i.e., listen to the word, mark the corresponding picture, and turn the page). A repeated measures ANOVA was conducted with test as the within-subject factor (pre- or post-test) and group (SF or No SF) as the between-subject factor. The main effect of test, $F(1, 68) = 1.33$, $p = 0.25$, the main effect of group, $F(1, 68) = 1.16$, $p = 0.29$, and the interaction effect of test x group, $F(1, 68) = 1.76$, $p = 0.19$, were not significant. Therefore, the SF and No SF groups were similar in their abilities to perform a picture-pointing word recognition task in quiet.

English competing speech. Figure 1 shows the mean percent correct scores of the SF and No SF group on the pre- and post-test of the English competing speech condition. Both groups performed similarly on the pre-test and post-test. For the pre-test, the mean percent correct score was 44.60% (SD = 18.93) for students in SF classrooms and 48.53% (SD = 15.68) for students in No SF classrooms. The post-test mean percent correct score was 57.60% (SD = 12.93) for the SF group and 57.20% (SD = 15.62) for the No SF group. A repeated measures ANOVA was conducted with test (pre-test or post-test) as the within-subject factor and group (SF or No SF) as the between-subject factor. The main effect of test, $F(1, 68) = 18.82$, $p = 0.00$, was significant indicating that the mean percent correct scores of the SF and No SF group improved significantly over time. The main effect of group, $F(1, 68) = 0.36$, $p = 0.55$, and the interaction effect of test x group, $F(1, 68) = 0.75$, $p = 0.39$, were not significant. Thus, while both groups improved over time, there was not a significant difference between the SF group and No SF group when the competing message was meaningful.

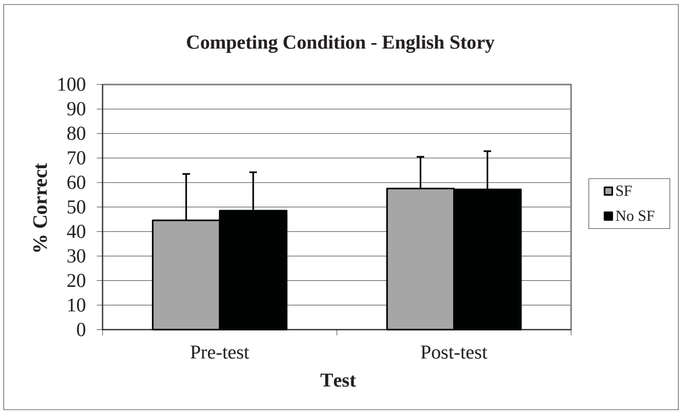


Figure 1. Mean percent correct scores for the soundfield amplification system (SF) and the no soundfield amplification system (No SF) classrooms on the pre- and post-test of the English competing story condition (Study One).

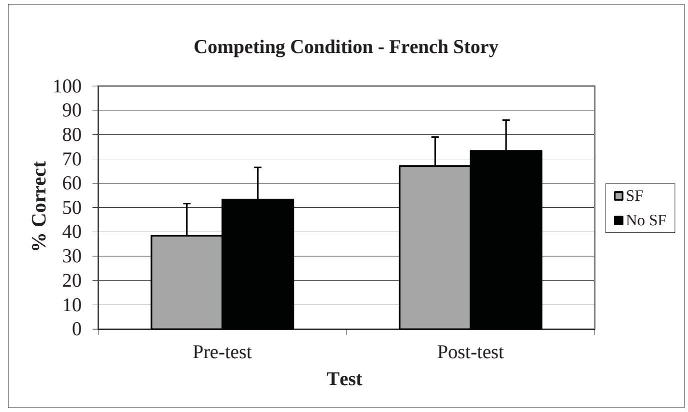


Figure 2. Mean percent correct scores for the soundfield amplification system (SF) and the no soundfield amplification system (No SF) classrooms on the pre- and post-test of the French competing story condition (Study One).

French competing speech. Figure 2 displays the mean percent correct scores of the SF classrooms and No SF classrooms on the pre- and post-test of the French competing speech condition. Students in the No SF group performed better than students in the SF group on the pre-test and post-test. The mean pre-test score of the SF group was 38.40% (*SD* = 13.24), and the mean pre-test score of the No SF group was 53.33% (*SD* = 13.18). Scores for both groups improved noticeably from the pre-test to the post-test. However, the mean post-test score of the No SF group was still greater than the mean post-test score of the SF group. On the post-test of the French competing speech condition, the mean score for the SF classrooms was 67.10% (*SD* = 11.90) while students in the No SF classrooms had an average score of 73.33% (*SD* = 12.62). A repeated measures ANOVA was performed with test (pre-test or post-test) as the within-subject factor and group (SF or No SF) as the between-subject factor. The main effect of test, $F(1, 68) = 121.02$, $p = 0.00$, was significant indicating that scores of the SF and No SF group improved significantly over time. The main effect of group, $F(1, 68) = 24.65$, $p = 0.00$, was also significant. Post hoc analysis revealed that the mean scores of the No SF group were significantly higher than the mean scores of the SF group on both the pre-test and the post-test. The interaction effect of test x group, $F(1, 68) = 3.86$, $p = 0.053$, approached the level of significance. Although performance of both groups improved over time, students in SF classrooms showed greater improvement from the pre-test to the post-test (Mean change = 28.70 percentage points) as compared to students in No SF classrooms (Mean change = 20.00 percentage points) when competing speech was not meaningful.

English vs. French. Results for the SF group and No SF group were analyzed separately to compare the change in scores from the pre-test to the post-test of the English versus the French competing speech condition (see Figure 3). The SF group's mean pre- to post-test change in scores was 13.00 percentage points (*SD* = 21.72) for the English condition and 28.70 percentage points (*SD* = 18.16) for the French condition. A one-way ANOVA revealed that the difference between the mean pre- to post-test change scores for the English and French competing condition was significant, $F(1, 78) = 12.30$, $p = 0.001$. Therefore, over the course of the study, students in the SF classrooms showed significantly greater improvement in their ability to ignore competing speech spoken in French as compared to their ability to ignore competing speech spoken in English. The No SF group's mean pre- to post-test change in scores was 8.67 percentage points (*SD* = 19.20) for the English condition and 20.00 percentage points (*SD* = 18.55) for the French condition. A one-way ANOVA revealed that the difference between the mean pre- to post-test change scores for the English and French competing condition was significant, $F(1, 58) = 5.41$, $p = 0.02$. Therefore, over the course of the study, students in the No SF classrooms also showed significantly greater improvement in their abilities to ignore competing speech spoken in French as compared to their abilities to ignore competing speech spoken in English.

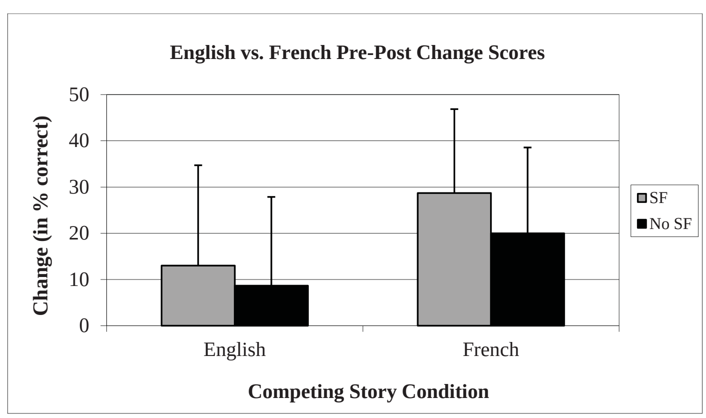


Figure 3. Mean pre- to post-test change scores (in percentage points) for the soundfield amplification system (SF) and the no soundfield amplification system (No SF) classrooms for the English and French competing story conditions (Study One).

Study Two

Study Two was a pilot study in which results from Study One were reanalyzed to investigate possible effects of children's ethnic background on selective auditory attention and effects of daily exposure to soundfield amplification on development of these skills. Normal developing children learn to use the language(s) and dialect(s) modeled by their parents/ caregivers. As a result, children from different ethnic backgrounds may differ in their exposure to and use of different dialects and languages. For example, some African American children use a dialect termed African American English (AAE); whereas, some Hispanic children use a dialect referred to as Spanish Influenced English (SIE). Educational instruction in the United States is typically based on the Standard American English (SAE) dialect (Craig, Thompson, Washington, & Potter, 2004). Therefore, some children's native dialect/ language may differ from the SAE dialect they are expected to use and understand at school. This mismatch could impact children's perception of speech in the classroom, thus potentially affecting learning. However, no published studies have specifically assessed effects of speaker-listener dialect differences on children's speech perception in quiet or in competing conditions.

Despite the lack of evidence specific to children, one study has investigated effects of dialect on adult listeners' speech perception in noise. Clopper and Bradlow (2008) compared adult listeners' abilities to understand target sentences spoken by talkers from four dialect regions of the United States (e.g., Mid-Atlantic, North, South, and General American). Target sentences were presented with speech-shaped noise at two signal-to-noise ratios (SNRs): -2 dB and -6 dB. Results revealed significant differences between percent words correct scores for all four dialect conditions when a -6 dB SNR was used. However, at the more favorable -2 dB SNR, no significant difference was seen between the Northern and Southern dialect conditions. These results suggest that the dialect of the target talker can have a significant impact on adult listener's abilities to understand speech in the presence of background noise. However, additional research is needed to further assess the relationship between dialect and speech perception for children and adults using target speech in other dialects (e.g., African American English, Spanish Influenced English, and Standard American English), and using different types of masking signals (e.g., noise, competing speech).

Although many questions remain unanswered regarding effects of dialectal differences, numerous studies have documented effects of listeners' language background on speech perception in competing conditions. The majority of evidence in this area comes from studies of monolingual and bilingual adult listeners (e.g., Mayo, Florentine, & Buus, 1997; Shi, 2009; Stuart, Zhang, & Swink, 2010; Takata & Nábělek, 1990; von Hapsburg, Champlin, & Shetty, 2004). However, a very small number of studies have investigated abilities of bilingual children to perceive their second language in the presence of competing noise or competing speech (Bovo & Callegari, 2009; Crandell & Smaldino, 1996; Nelson, Kohnert, Sabur, & Shaw, 2005). Results from these studies reveal several key findings. First, in quiet listening conditions, monolingual and bilingual children tend to perform similarly (Crandell & Smaldino, 1996; Nelson et al., 2005). However, in the presence of competing speech, bilingual children need a better SNR than monolingual children in order to achieve 50% intelligibility for target words (Bovo & Callegari, 2009). In addition, bilingual children perform significantly poorer than monolingual children on speech recognition tasks at SNRs ranging from -6 dB to +10 dB (Crandell & Smaldino, 1996; Nelson et al., 2005), with the difference between groups increasing as the SNR declines (i.e., becomes less optimal; Crandell & Smaldino, 1996). Previous studies have shown that typical classrooms often have SNRs less than +10 dB (Flexer, 2005). As such, bilingual children are likely to experience more severe listening difficulties than monolingual children in typical classroom conditions, which could impact learning when classroom instruction is in the children's second language.

To date, limited data exist regarding potential effects of soundfield amplification for children of different ethnicities and/or dialects. However, available evidence does suggest that soundfield amplification can positively impact ESL children's abilities to listen in the classroom. Crandell (1996) assessed speech perception performance for 8- to 10-year-old ESL children in unamplified and amplified conditions designed to simulate a typical classroom environment. In the unamplified condition, children listened to monosyllabic words presented in multi-talker babble in three SNR conditions: +6 dB, +1 dB, and -2 dB. In the amplified condition, the target words were presented through a soundfield amplification system at three more favorable SNRs: +16 dB, +10 dB, and +8 dB. Speech perception performance of the ESL children was significantly better in the amplified condition. Therefore, soundfield amplification is one method of helping ESL children understand speech in noisy classroom conditions.

Together, existing evidence demonstrates that children's speech perception in competing conditions can be affected by their language background, but additional research is needed to investigate factors such as ethnicity and dialect. The target population of Study One included first grade students with an English primary language background and no known significant hearing loss. Students' ethnic background was not considered when recruiting schools, classrooms, or students. However, as a matter of coincidence, the eight participating classrooms came from schools with distinct ethnic backgrounds. Four classrooms (two SF and two No SF) were from a school with a primarily African American student population (School A), and the remaining 4 classrooms were located in two schools (one SF and one No SF classroom at each school) with primarily Hispanic student populations (School B and C). For ease of understanding, School A will be referred to as "School PAA" (predominantly African American), and Schools B and C will collectively be referred to as "School PH" (predominantly Hispanic).

Because of their predominantly Hispanic background, it was presumed that students in School PH classrooms were more likely to have been exposed to a second language (i.e., most likely Spanish). On the other hand, it was presumed that students in classrooms with a predominantly African American background were less likely to have had any significant exposure to a second language, but may have used a dialect other than SAE (e.g., AAE). In light of these differences, Study Two was conducted as a pilot study in which results from Study One were reanalyzed to:

- Compare selective auditory attention skills of normal hearing first grade students from a primarily Hispanic background to those from a primarily African American background,
- Investigate how effects of the meaning of competing speech may differentially affect selective auditory attention performance of children from different ethnic backgrounds, and
- Assess effects of daily exposure to soundfield amplification on development of selective auditory attentions skills for children from a primarily Hispanic background versus those from a primarily African American background.

Method

Study Two involved reanalyzing data collected during Study One. As described in Study One, all participating subjects spoke English as their primary language as per teacher report. In planning the original study, permission was not requested to obtain information regarding each student's ethnicity, dialect, and/or exposure to a second language. However, information provided by the school district revealed that the overall ethnic composition of each participating school was as follows:

- School A - 25% Hispanic, 71% African American, 4% Anglo/Other
- School B - 96% Hispanic, 1% African American, 3% Anglo/Other
- School C - 81% Hispanic, 10% African American, 9% Anglo/Other

As previously mentioned, the three schools were relabeled for ease of understanding in the pilot study. Specifically, the School A group was labeled "School PAA" (predominantly African American), and Schools B and C were grouped together under the name "School PH" (predominantly Hispanic). As shown in Tables 1 and 2, the ethnic composition of each participating classroom was similar to that of each school, with students in the School PAA classrooms being primarily African American (Mean = 73% of the students) and students in the School PH classrooms being primarily Hispanic (Mean = 82%).

Results

The School PAA and School PH groups differed in their ethnic background and potentially in their exposure to a second language. However, due to the nature of dividing the participants into groups, the schools had an unequal number of subjects in groups that were fairly small (range of 11 to 25 subjects per group). As such,

Table 1. School PAA (predominantly African American) - Ethnic composition of each classroom (percentage of students per ethnic group).

Classroom	African American	Hispanic	White
C (SF)	75%	18.75%	6.25%
D (SF)	68.75%	25%	6.25%
E (No SF)	75%	25%	0%
F (No SF)	75%	18.75%	6.25%

Table 2. Schools PH (predominantly Hispanic) – Ethnic composition of each classroom (percentage of students per ethnic group).

Classroom	African American	Hispanic	White
A (No SF)	7.69%	84.62%	7.69%
B (SF)	0%	100%	0%
G (No SF)	14.29%	76.19%	9.52%
H (SF)	10.53%	73.68%	15.79%

results for each school were analyzed separately to determine if the two groups were also distinct in their development of selective auditory attention skills and their responsiveness to soundfield amplification.

School PAA. School PAA included 15 students in the SF group and 11 students in the No SF group. In Study One, NU-CHIPS words were administered in quiet prior to selective auditory attention testing to ensure that students could perform a picture-pointing word recognition task. On the pre-test, mean percent correct scores were 93.33% (*SD* = 5.16) for students in School PAA SF classrooms and 83.20% (*SD* = 12.62) for students in School PAA No SF classrooms. A one-way ANOVA was conducted to compare the mean score for the SF and No SF group on the pre-test of the NU-CHIPS. Results indicated that the mean score for the SF group was significantly higher (i.e., better) than the mean score for the No SF group, $F(1, 23) = 7.84$, $p = 0.01$. However, the difference was only equivalent to 2.5 words out of the 25 total words included on the NU-CHIPS pre-test. Furthermore, the mean scores for the SF group (93.33%) and No SF group (83.20%) both represent "good" word recognition abilities according to clinical standards. As such, these results suggest that students in the School PAA SF and No SF group were able to understand and perform the task (i.e., listen to the word, mark the corresponding picture, turn the page, etc.).

Figure 4 displays the mean percent correct scores of School PAA students on the English competing story condition. At the pre-test, students in SF classrooms (*M* = 61.60%, *SD* = 14.00) performed better than students in No SF classrooms (*M* = 52.37%, *SD* = 19.74). However, the post-test mean percent correct scores of the SF group (*M* = 55.73%, *SD* = 12.96) and No SF group (*M* = 55.27%, *SD* = 17.69) were essentially equal. A repeated measures ANOVA was performed using test (pre-test or post-test) as the within-subject factor and group (SF or No SF) as the between-subject factor. The main effect of test, $F(1, 24) = 0.29$, $p = 0.60$, the main effect of group, $F(1, 24) = 0.72$, $p = 0.40$, and the interaction effect of test x group, $F(1, 24) = 1.85$, $p = 0.19$, were not significant. Thus, students in classrooms with a predominantly African American background did not improve significantly over time, and there was not a significant effect of daily exposure to soundfield amplification on their selective auditory attention performance when the competing story was meaningful.

Figure 5 shows the mean percent correct scores of the School PAA SF and School PAA No SF students on the pre-test and post-test of the French competing story condition. The mean score of the No SF group was noticeably higher than the mean score of the SF group on both the pre-test and the post-test. On the pre-test, the mean score was 53.45% (*SD* = 14.12) for the No SF group and 39.73% (*SD* = 15.38) for the SF group. Scores for both groups improved from the pre-test to the post-test, but the No SF group still scored higher than the SF group on the post-test. On the post-test of the French story condition, mean scores were 78.91% (*SD* = 12.91) for No SF students and 63.47% (*SD* = 11.89) for SF students. A repeated measures ANOVA was conducted using the School PAA students' scores on the French story condition with test (pre-test or post-test) as the within-subject factor and group (SF or No SF) as the between-subject factor. The main effect of test, $F(1, 24) = 35.79$, $p = 0.00$, was significant indicating that mean scores of the SF and No SF group improved significantly over time. The main effect of group, $F(1, 24) = 17.03$, $p = 0.00$, was also significant. Post hoc analysis revealed that there was a significant difference between performance of the SF and the No SF group on both the pre-test and the post-test. The interaction effect of test x group, $F(1, 24) = 0.04$, $p = 0.84$, was not significant. As such, there was not a significant effect of daily use of soundfield amplification on the selective auditory attention performance of School PAA

Figure 4. Mean percent correct scores for School PAA (predominantly African American) in soundfield amplification system (SF) and no soundfield amplification system (No SF) classrooms on the pre- and post-test of the English competing story condition (Study Two).

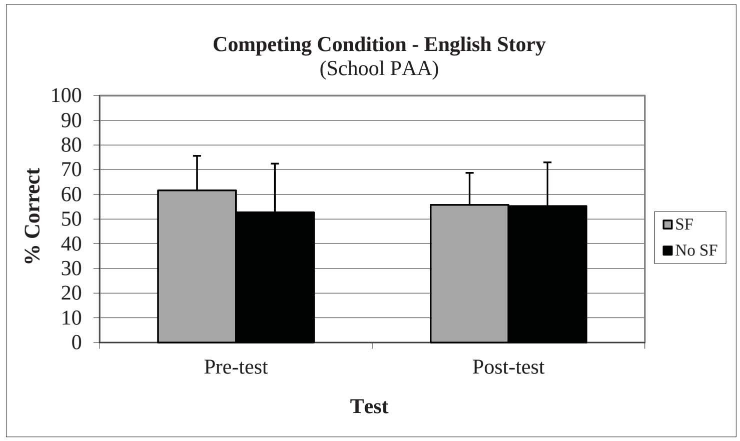
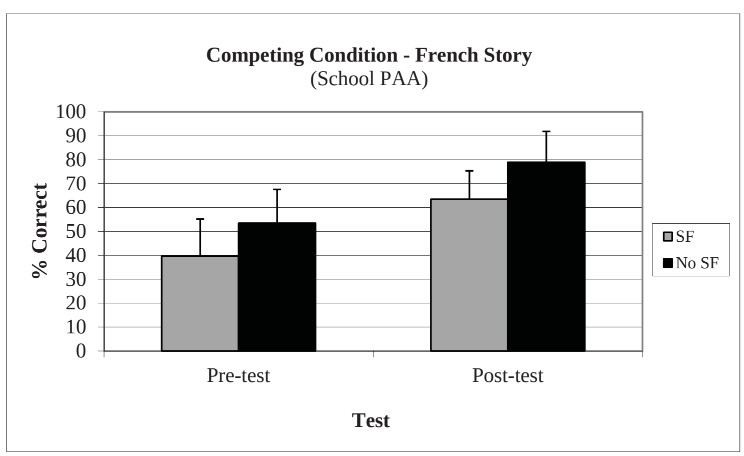


Figure 5. Mean percent correct scores for School PAA (predominantly African American) in soundfield amplification system (SF) and no soundfield amplification system (No SF) classrooms on the pre- and post-test of the French competing story condition (Study Two).



students when the competing message was not meaningful.

School PH. School PH included 25 students in the SF group and 19 students in the No SF group. Mean pre-test scores on the NU-CHIPS were compared for the School PH SF and No SF classrooms. On the pre-test, mean percent correct scores were 94.40% (*SD* = 5.16) for students in SF classrooms and 92.60% (*SD* = 7.82) for students in No SF classrooms. These scores suggest that both groups understood and could perform the task (i.e., listen to the word, mark the corresponding picture, turn the page, etc.). A one-way ANOVA revealed no significant difference between the mean score for the SF and the No SF group, $F(1, 43) = 0.86$, $p = 0.36$. Therefore, the School PH SF and No SF groups were similar in their abilities to perform a picture-pointing word recognition task in quiet.

Figure 6 displays the mean percent correct scores for students in the School PH SF and No SF classrooms on the English competing story condition. Pre-test performance of students in No SF classrooms (*M* = 46.10%, *SD* = 12.74) was better than performance of students in SF classrooms (*M* = 34.40%, *SD* = 13.37). Both groups improved over time, such that performance of the two groups was essentially equal at the post-test. The post-test mean percent correct score was 58.72% (*SD* = 13.05) for the SF group and 58.32% (*SD* = 14.69) for the No SF group. A repeated measures ANOVA was performed with the within-subject factor being test (pre-test or post-test), and the between-subject factor being group (SF or No SF). The main effect of test, $F(1, 42) = 43.03$, $p = 0.00$, and the interaction effect of test x group, $F(1, 42) = 4.73$, $p = 0.04$, were significant, indicating that selective auditory attention performance for students in the SF and No SF classrooms improved significantly from the pre-test to the post-test. However, the significant interaction effect reveals that School PH SF students showed significantly greater improvement over time than School PH No SF students when the competing speech was meaningful (i.e., spoken in English). The main effect of group, $F(1, 42) = 3.55$, $p = 0.07$, was not significant.

Mean percent correct scores for School PH students on the French competing story condition are shown in Figure 7. On the pre-test, the No SF group (*M* = 53.26%, *SD* = 13.0) performed better than the SF group (*M* = 37.60%, *SD* = 12.06). Performance of SF students and No SF students improved from the pre-test to the post-test. However, SF students showed greater improvement to the extent that they were able to "catch up" with the No SF students on the post-test. The post-test mean score of the SF group was 69.28% (*SD* = 11.59) as compared to a mean score of 70.11% (*SD* = 11.58) for the No SF group. A repeated measures ANOVA was performed. The within-subject factor was test (pre-test or post-test), and the between-subject factor was group (SF or No SF). The main effect of test, $F(1, 42) = 93.31$, $p = 0.00$, was significant. Performance of students in SF and No SF classrooms improved significantly over time from the pre-test to the post-test. The main effect of group, $F(1, 42) = 9.56$, $p = 0.00$, was also significant indicating that there was a significant difference between scores of the SF group and the No SF group. Post hoc analysis revealed that this significance between group difference was only present on the pre-test of the French story condition. The interaction effect of test x group, $F(1, 42) = 8.73$, $p = 0.01$, was also significant, which demonstrates that SF students showed significantly greater improvement from the pre-test to the post-test than No SF students. These findings suggest that for students in School PH classrooms, daily exposure to soundfield amplification may have had a significant positive effect on their ability to ignore competing speech that was not meaningful.

Figure 6. Mean percent correct scores for School PH (predominantly Hispanic) in soundfield amplification system (SF) and no soundfield amplification system (No SF) classrooms on the pre- and post-test of the English competing story condition (Study Two).

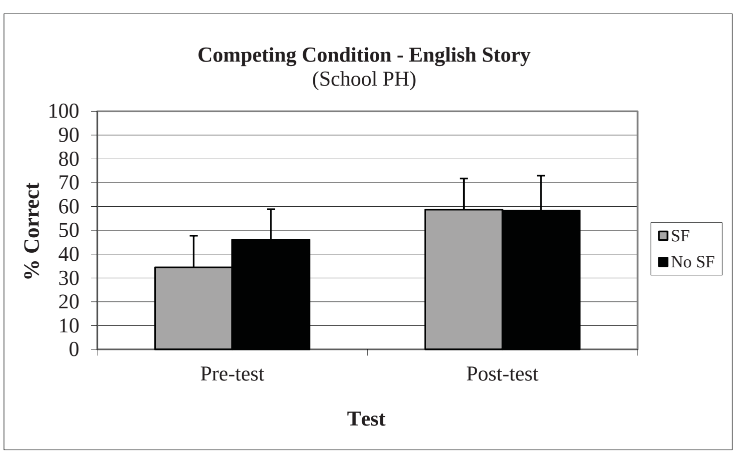
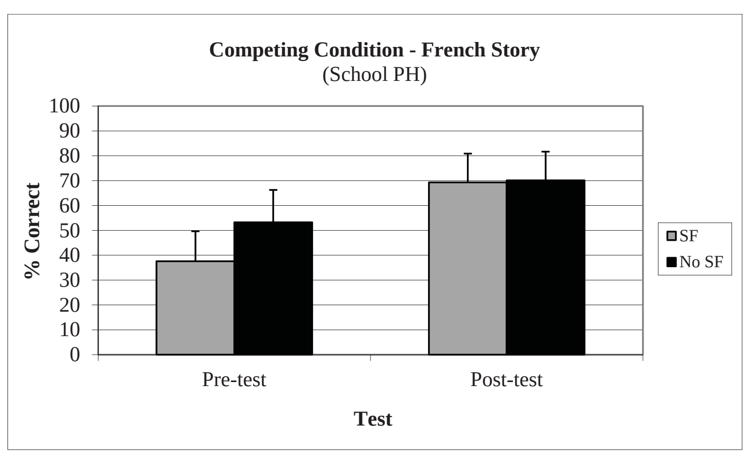


Figure 7. Mean percent correct scores for School PH (predominantly Hispanic) in soundfield amplification system (SF) and no soundfield amplification system (No SF) classrooms on the pre- and post-test of the French competing story condition (Study Two).



General Discussion

Study One

Two purposes of Study One included investigating (1) children's development of selective auditory attention, and (2) effects of the meaning of competing speech on the ability to selectively attend. To assess development, selective auditory attention testing was administered at the beginning and end of the students' second semester in first grade. To evaluate effects of the meaning of competing speech, word recognition testing was performed with competing speech spoken in English (i.e., the native language) and French (i.e., an unfamiliar language). Analysis of results revealed several key findings. First, the SF and No SF group each improved significantly in their ability to selectively attend to the target speech signal in the presence of competing speech spoken in English and French. This pattern is consistent with findings from previous studies showing that children's selective auditory attention skills improve significantly with increasing age (Cherry, 1981; Doyle, 1973; Geffen & Sexton, 1978; Macoby & Konrad, 1966; Sexton & Geffen, 1979). Second, analysis of results revealed that both groups showed significantly greater improvement in the French competing speech condition. At the pre-test, there was no significant difference between each group's (i.e., SF or No SF) scores in the English and French competing conditions, but at the post-test, students' scores were significantly better in the French condition. This pattern was seen for both the SF and the No SF group, suggesting that the ability to ignore non-meaningful competing speech may develop more rapidly than the ability to ignore meaningful competing speech. This finding is consistent with previous research showing that children's selective auditory attention performance is affected differently depending on the content of the competing signal (Cherry, 1981; Cherry & Kruger, 1983). However, previous studies have only investigated children's abilities to ignore English speech, white noise, and backwards speech. With the exception of the current study, there is a paucity of research examining how meaning and other linguistic characteristics, such as language rhythm, may affect children's selective auditory attention. Future studies should investigate children's abilities to ignore different types of competing speech signals, such as meaningful speech, grammatical but non-meaningful speech, ungrammatical strings of words, and speech spoken in different languages. Data from children of different ages could then be compared to determine whether the ability to ignore each type of competing speech signal develops at a different rate.

A third purpose of Study One was to objectively measure effects of daily exposure to soundfield amplification on children's development of selective auditory attention. Mean word recognition scores for English and French competing speech conditions were compared for first grade students in classrooms with soundfield amplification (experimental or SF classrooms) and classrooms without soundfield amplification (control or No SF classrooms). For the English competing speech condition, there were no significant differences between mean scores of the SF and No SF group, indicating no significant effect of daily exposure to soundfield amplification. For the French competing speech condition, students in SF classrooms showed greater improvement from the pre-test to the post-test than students in No SF classrooms. This difference approached the level of significance ($p = 0.053$), indicating a possible positive effect of daily exposure to soundfield amplification. Given that the SF and No SF group both showed significantly greater improvement in the French competing speech condition, these results may indicate that the ability to ignore non-meaningful competing speech was developing more rapidly than the ability to ignore meaningful competing speech. If maturation was driving these aspects of selective auditory attention to develop at different rates, daily exposure to soundfield amplification may have simply enhanced this natural trend. As such, a similar effect of soundfield amplification might have occurred in the English competing speech condition if the study had covered a longer period of time. Therefore, additional research is needed to investigate how longer exposure to soundfield amplification may affect children's development of different aspects of selective auditory attention.

Although Study One did not show a robust positive effect of soundfield amplification, the results demonstrate that daily exposure to amplified speech did not negatively impact the children's development of selective auditory attention. Previous studies have shown immediate improvements in speech intelligibility (Eriks-Brophy & Ayukawa, 2000; Flexer et al., 1990), spelling performance (Zabel & Tabor, 1993), and classroom behavior (Eriks-Brophy & Ayukawa, 2000; Palmer, 1998) when testing is conducted with a soundfield system in use. Therefore, use of soundfield amplification in the current experimental classrooms may have resulted in immediate improvements in the students' speech understanding in classroom noise, but these immediate effects may not have been strong enough to affect the students' underlying development of selective auditory attention.

Study Two

Study Two was a pilot study in which results from Study One were reanalyzed to compare selective auditory attention skills of children from different ethnic backgrounds. Students at School PAA were from a predominantly African American background; whereas, students at School PH were from a predominately Hispanic background. Although all students reportedly spoke

English as their primary language, students at School PAA and School PH may have differed in their use of and exposure to different dialects and/or languages. Given the limited evidence available regarding effects of dialect and second language exposure on children's speech perception, two purposes of Study Two were to (1) compare development of selective auditory attention skills for normal hearing first grade students from a primarily Hispanic background (School PH) to those from a primarily African American background (School PAA), and (2) investigate whether effects of the meaning of competing speech might differentially affect selective auditory attention performance of children from different ethnic backgrounds. Results for School PAA and School PH were analyzed separately due to unequal sample sizes.

Data collected for School PAA revealed that the SF and No SF groups both improved significantly in their ability to selectively attend when competing speech was spoken in French, but not when competing speech was spoken in English. In contrast, the School PH SF and No SF group both showed significant improvement in their mean scores for the English and French competing speech conditions. All participating students from School PAA and School PH were known to use English as their primary language. Therefore, it was presumed that for both groups, English competing speech would be meaningful; whereas, French competing speech would not be meaningful. However, in both competing speech conditions (i.e., English and French), performance of School PH students was similar to how School PAA students performed in the French competing story condition.

One possible explanation is that exposure to a second language may have influenced students from the predominantly Hispanic classrooms (School PH), such that they perceived the English and French competing speech differently than students from the predominantly African American classrooms (School PAA). Although School PH students were known to use English as their primary language, they were potentially more likely to have been exposed to a second language (i.e., Spanish) in the home environment. Previous research has shown that monolingual and bilingual adult listeners' speech perception is affected by their familiarity with the language in which competing speech is spoken (e.g., Garcia Lecumberri & Cooke, 2006). In addition, recent evidence suggests that monolingual adult listeners are sensitive to underlying linguistic properties of the language of competing speech, even when competing speech is spoken in an unfamiliar language. For example, Reel and Hicks (in press) found no significant differences between monolingual English-speaking adults' selective auditory attention performance when competing speech was spoken in English or German, two languages that share a number of linguistic properties, including lexical roots and rhythmic structure (e.g., Grabe & Low, 2002). These results suggest that a listener's familiarity with linguistic properties of the language of competing speech may impact selective auditory attention, even if competing speech is spoken in an unfamiliar language. Given these findings, exposure to a second language may have impacted how School PH students selectively attended to the competing speech spoken in English, their native language, and French, an unfamiliar language that shares linguistic properties with Spanish (e.g., Sebastián-Gallés, Dupoux, Costa, & Mehler, 2000). However, this conclusion is only speculative considering that information was not collected regarding whether the participating students had in fact been exposed to a second language. Future studies should, therefore, gather information regarding each child's language exposure and investigate how exposure to a second language may affect development of different aspects of selective auditory attention, even for students who are not fluent in their second language.

In addition to potential differences in language exposure, dialectical differences between School PAA and School PH students may have also influenced their selective auditory attention performance. English was a familiar language for all participating students. However, students in School PAA may have used AAE dialect; whereas, students in School PH may have used SIE dialect. The English competing speech was spoken in SAE dialect; therefore, the degree of mismatch between the dialect used for the English competing speech (i.e., SAE) and the dialect used by each group of students (i.e., possibly SIE or AAE) may have affected their selective attention. Although a few studies have investigated the impact of second language experience on children's selective auditory attention (e.g., Bovo & Callegari, 2009; Crandell & Smaldino, 1996; Nelson et al., 2005), no studies have been conducted to determine how dialect differences may impact their abilities to selectively attend. One question of interest is whether the degree of mismatch between the dialect of the speaker and the dialect of the listener may impact speech perception in competing conditions. Future studies should, therefore, gather specific information on the dialect of the target talker and the participating listeners in order to investigate how dialect may affect selective auditory attention development in children.

A third purpose of Study Two was to compare effects of daily exposure to soundfield amplification on development of selective auditory attentions skills for children from a primarily Hispanic background versus those from a primarily African American background. For School PAA, daily exposure to soundfield amplification had no significant effect on students' selective auditory attention development in the English or French competing speech condition. In contrast, students in SF classrooms at School PH showed significantly greater improvement in their ability to ignore competing speech in English and French, as compared to students in the School PH No SF classrooms. Therefore, daily exposure to soundfield amplification only improved the selective auditory attention development of School PH students, a finding that may be related to their possible exposure to a second language in the home environment. Previous research has shown that children who speak English as a second language have greater difficulties understanding speech in background noise conditions than do monolingual children (e.g., Crandell & Smaldino, 1996). Furthermore, there is evidence that ESL children show significant improvements in their ability to perceive speech in background noise when using soundfield amplification (Crandell, 1996). However, there is currently a lack of research investigating how exposure to soundfield amplification may affect the selective auditory attention development of children who have been exposed to, but are not fluent in, a second language.

Conclusions

Taken as a whole, results of the current study indicate use of soundfield amplification does not hinder development of selective auditory attention over time. This is important given that previous studies have shown immediate benefits for selective auditory attention when soundfield amplification is used in the classroom (e.g., Mendel et al., 2003). In Study One, daily exposure to soundfield amplification did not significantly affect development of selective auditory attention skills among normal-hearing first grade students. However, there was a borderline significant ($p = 0.053$) effect of soundfield amplification in the French competing story condition, with the SF group showing greater improvement from pre-test to post-test than the No SF group. This finding indicates a possible positive effect of soundfield amplification on development of the ability to selectively attend to target speech while ignoring competing speech that lacks meaning.

Study Two was performed to provide pilot results that could be used to determine whether the relationship between ethnicity, selective auditory attention, and soundfield amplification warranted further investigation. Results revealed a different pattern of selective auditory attention development for students from a predominately African American school as compared to students from a predominately Hispanic school, with the two schools differing in their response to the semantic content of the competing speech message. Furthermore, preliminary results from Study Two indicate that exposure to soundfield amplification may affect development of selective auditory attention skills among certain groups of children, such as those exposed to a second language and/or a second dialect. However, these findings are only speculative in nature, given that specific information was not collected regarding each student's dialect usage and exposure to a second language.

Additional research is needed to further investigate the findings of Study One and Study Two. For example, future studies should examine whether a significant effect of soundfield amplification would occur if students were exposed to the amplified signal over a period of time longer than the four month course of the current study. Attempts should also be made to more closely monitor the acoustical conditions in the participating classrooms to ensure that the SF classrooms are able to achieve and maintain a significantly higher SNR than those of the No SF classrooms. Finally, studies should collect data regarding each student's ethnicity, dialect, and language background in order to assess effects of these factors on development of selective auditory attention. Future studies should also consider how exposure to soundfield amplification may affect the development of such skills among children from different ethnic, dialect, and/or language backgrounds. Together, results of such studies could lead to (1) identification of previously overlooked groups of children who may be at risk for listening difficulties in noisy classroom conditions (e.g., children from different dialect backgrounds), and (2) the design of new intervention strategies to improve classroom listening (and potentially learning) for children who struggle to attend to target speech in the presence of competing sounds.

Acknowledgements

We gratefully acknowledge Dr. Rajinder Koul, Dr. Katsura Aoyama, Dr. Renée Bogschutz, and Sherry Sancibrian at the Texas Tech University Health Sciences Center for their contributions to this project. We would also like to thank the students, teachers, and administrators at the participating schools, as well as all other individuals who generously gave their time to make the study a success.

References

American National Standards Institute. (2002). *Acoustical performance criteria, design requirements and guidelines for schools* (ANSI S12.60-2002). New York: Author.

American Speech-Language-Hearing Association. (2005). *Acoustics in educational settings: Position statement*. Retrieved from http://www.asha.org/members/deskref-journals/deskref/default

Bess, F. H., Sinclair, J., & Riggs, D. (1984). Group amplification in schools for the hearing-impaired. *Ear and Hearing, 5,* 138-144.

Bovo, R., & Callegari, E. (2009). Effects of classroom noise on the speech perception of bilingual children learning in their second language: Preliminary results. *Audiological Medicine*, *7*(4), 226-232.

Bradley, J. S. (1986). Speech intelligibility studies in classrooms. *Journal of the Acoustical Society of America, 80*(3), 846-854.

Brungart, D. S. (2001). Informational and energetic masking effects in the perception of two simultaneous talkers. *Journal of the Acoustical Society of America, 109*(3), 1101 – 1109.

Chermak, G. D., & Zielonko, B. (1977). Word discrimination in the presence of competing speech with children. *Journal of the American Audiology Society, 2*(5), 188-192.

Cherry, R. S. (1981). Development of selective auditory attention skills in children. *Perceptual and Motor Skills, 52*, 379-385.

Cherry, R. S., & Kruger, B. (1983). Selective auditory attention abilities of learning disabled and normal achieving children. *Journal of Learning Disabilities, 16*(4), 202-205.

Clopper, C. G., & Bradlow, A. R. (2008). Perception of dialect variation in noise: Intelligibility and classification. *Language and Speech, 51*(3), 175-198.

Cooke, M., Garcia Lecumberri, M. L., & Barker, J. (2008). The foreign language cocktail party problem: Energetic and informational masking effects in non-native speech perception. *Journal of the Acoustical Society of America, 123*(1), 414-427.

Cool Edit Pro (Version 2) [Computer software]. (2002). Phoenix, AZ: Syntrillium Software Corporation.

Craig, H., Thompson, C., Washington, J., & Potter, S. (2004). Performance of elementary-grade African American students on the Gray Oral Reading tests. *Language, Speech, & Hearing Services in the Schools, 35,* 141-154.

Crandell, C. C. (1993). Speech recognition in noise by children with minimal degrees of sensorineural hearing loss. *Ear and Hearing, 14*(3), 210-215.

Crandell, C. C. (1996). Effects of sound-field FM amplification on the speech perception of ESL children. *Educational Audiology Monograph, 4,* 1-5.

Crandell, C. C., & Smaldino, J. J. (1996). Speech perception in noise by children for whom English is a second language. *American Journal of Audiology, 5*(3), 47-51.

Crandell, C. C., & Smaldino, J. J. (2000). Room acoustics for listeners with normal-hearing and hearing impairment. In M. Valente, H. Hosford-Dunn, & R.J. Roeser (Eds.), *Audiology treatment* (pp. 601-637). New York: Thieme Medical.

Darai, B. (2000, July 10). Using sound field FM systems to improve literacy scores. *Advance for Speech-Language Pathologists & Audiologists,* 1-2.

Doyle, A. (1973). Listening to distraction: A developmental study of selective attention. *Journal of Experimental Child Psychology, 15,* 100-115.

Elliott, L. L. (1979). Performance of children aged 9 to 17 years on a test of speech intelligibility in noise using sentence material with controlled word predictability. *Journal of the Acoustical Society of America, 66*(3), 651-653.

Elliott, L. L., Connors, S., Kille, E., Levin, S., Ball, K., & Katz, D. (1979). Children's understanding of monosyllabic nouns in quiet and in noise. *Journal of the Acoustical Society of America, 66*(1), 12-20.

Elliott, L. L., & Katz, D. R. (1980). *Northwestern University Children's Perception of Speech (NU-CHIPS): Technical manual*. St. Louis, MO: AUDITEC.

Eriks-Brophy, A., & Ayukawa, H. (2000). The benefits of sound field amplification in classrooms of Inuit students in Nunavik: A pilot project. *Language, Speech, & Hearing Services in Schools, 31*, 324-335.

Finitzo-Hieber, T., & Tillman, T. W. (1978). Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. *Journal of Speech and Hearing Research, 21,* 440-457.

Flexer, C. (1995). Classroom amplification systems. In R. J. Roeser & M. P. Downs (Eds.), *Auditory disorders in school children* (3rd ed., pp. 235-260). New York: Thieme Medical.

Flexer, C. (2005). Rationale for the use of sound field systems in classrooms: The basis of teacher in-services. In C. C. Crandell, J. J. Smaldino, & C. Flexer (Eds.), *Sound field amplification: Applications to speech perception and classroom acoustics* (2nd ed., pp. 3-22). Clifton Park, NY: Thomson Delmar Learning.

Flexer, C., Millin, J. P., & Brown, L. (1990). Children with developmental disabilities: The effect of sound field amplification on word identification. *Language, Speech, & Hearing Services in Schools, 21*, 177-182.

Freyman, R. L., Balakrishnan, U., & Helfer, K. S. (2001). Spatial release from informational masking in speech recognition. *Journal of the Acoustical Society of America, 109*(5), 2112-2122.

Freyman, R. L., Balakrishnan, U., & Helfer, K. S. (2004). Effect of number of masking talkers and auditory priming on informational masking in speech recognition. *Journal of the Acoustical Society of America, 115*(5), 2246-2256.

Garcia Lecumberri, M. L., & Cooke, M. (2006). Effect of masker type on native and non-native consonant perception in noise. *Journal of the Acoustical Society of America, 119*(4), 2445-2454.

Geffen, G., & Sexton, M. A. (1978). The development of auditory strategies of attention. *Developmental Psychology, 14*(1), 11-17.

Grabe, E., & Low, E. L. (2002). Durational variability in speech and the rhythmic class hypothesis. *Papers in Laboratory Phonology, 7*, 1-16.

Johnson, C. E. (2000). Children's phoneme identification in reverberation and noise. *Journal of Speech, Language, and Hearing Research, 43*(1), 144-157.

Klatte, M., Lachmann, T., & Meis, M. (2010). Effects of noise and reverberation on speech perception and listening comprehension of children and adults in a classroom-like setting. *Noise & Health, 12*(49), 270-282.

Knecht, H. A., Nelson, P. B., Whitelaw, G. M., & Feth, L. L. (2002). Background noise levels and reverberation times in unoccupied classrooms: Predictions and measurements. *American Journal of Audiology, 11*, 65-71.

Larsen, J. B., & Blair, J. C. (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. *Language, Speech, and Hearing Services in Schools, 39*, 451-460.

Leech, R., Aydelott, J., Symons, G., Carnevale, J., & Dick, F. (2007). The development of sentence interpretation: Effects of perceptual, attentional, and semantic interference. *Developmental Science, 10*(6), 794-813.

Maccoby, E. E., & Konrad, K. W. (1966). Age trends in selective listening. *Journal of Experimental Child Psychology, 3*, 113-122.

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of Speech, Language, and Hearing Research, 40*, 686-693.

McSporran, E., & Butterworth, Y. (1997). Sound field amplification and listening behaviour in the classroom. *British Educational Research Journal, 23*(1), 81-97.

Mendel, L. L., Roberts, R. A., & Walton, J. H. (2003). Speech perception benefits from sound field FM amplification. *American Journal of Audiology, 12*, 114-124.

Nábělek, A. K., & Robinson, P. K. (1982). Monaural and binaural speech perception in reverberation for listeners of various ages. *Journal of the Acoustical Society of America, 71*(5), 1242-1247.

Nelson, P., Kohnert, K., Sabur, S., & Shaw, D. (2005). Classroom noise and children learning through a second language: Double jeopardy? *Language, Speech, and Hearing Services in Schools, 36*, 219-229.

Neuman, A. C., & Hochberg, I. (1983). Children's perception of speech in reverberation. *Journal of the Acoustical Society of America, 73*(6), 2145-2149.

Neuman, A. C., Wroblewski, M., Hajicek, J., & Rubinstein, A. (2010). Combined effects of noise and reverberation on speech recognition performance of normal-hearing children and adults. *Ear & Hearing, 31*(3), 336-344.

Palmer, C. V. (1998). Quantification of the ecobehavioral impact of a soundfield loudspeaker system in elementary classrooms. *Journal of Speech, Language, & Hearing Research, 41*, 819-833.

Papso, C. F., & Blood, I. M. (1989). Word recognition skills of children and adults in background noise. *Ear and Hearing, 10*(4), 235-236.

Perrault, C. (n.d.). *Classique: Cendrillon*. Retrieved from http://www.jecris.com/TXT/CONTES/CENDRILLON/cendrillon1.html

Picard, M., & Bradley, J. S. (2001). Revisiting speech interference in classrooms. *Audiology, 40*(5), 221-244.

Purcell, N., & Millett, P. (2010). Effect of sound field amplification on grade 1 reading outcomes. *Canadian Journal of Speech-Language Pathology and Audiology, 34*(1), 17-24.

Reel, L. A., & Hicks, C. B. (in press). Selective auditory attention in adults: Effects of rhythmic structure of the competing language. *Journal of Speech, Language, and Hearing Research*.

Rhebergen, K. S., Versfeld, N. J., & Dreschler, W. A. (2005). Release from informational masking by time reversal of native and non-native interfering speech (L). *Journal of the Acoustical Society of America, 118*(3), 1274-1277.

Rosenberg, G. G. (1998). Relocatable classrooms: Acoustical modifications or FM sound field classroom amplification? *Journal of Educational Audiology, 6*, 9-13.

Rosenberg, G. G., & Blake-Rahter, P. (1995). In-service training for the classroom teacher. In C. C. Crandell, J. J. Smaldino, & C. Flexer (Eds.), *Sound-field FM amplification: Theory and practical applications* (pp. 149-190). San Diego, CA: Singular Publishing.

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

Ross, M., & Lerman, J. (1970). A picture identification test for hearing-impaired children. *Journal of Speech and Hearing Research, 13*, 44-53.

Ryan, S. (2009). The effects of a sound-field amplification system on managerial time in middle school physical education settings. *Language, Speech, and Hearing Services in Schools, 40*, 131-137.

Sapienza, C. M., Crandell, C. C., & Curtis, B. (1999). Effects of sound-field frequencymodulation amplification on reducing teachers' sound pressure level in the classroom. *Journal of Voice, 13*(3), 375-381.

Sebastián-Gallés, N., Dupoux, E., Costa, A., & Mehler, J. (2000). Adaptation to time-compressed speech: Phonological determinants. *Perception & Psychophysics, 62*(4), 834-842.

Sexton, M. A., & Geffen, G. (1979). Development of three strategies of attention in dichotic monitoring. *Developmental Psychology, 15*(3), 299-310.

Shi, L. (2009). Normal-hearing English-as-a-second-language listeners' recognition of English words in competing signals. *International Journal of Audiology, 48*, 260-270.

Simpson, S. A., & Cooke, M. (2005). Consonant identification in N-talker babble is a nonmonotonic function of N (L). *Journal of the Acoustical Society of America, 118*(5), 2775-2778.

Stuart, A. (2008). Reception thresholds for sentences in quiet, continuous noise, and interrupted noise in school-age children. *Journal of the American Academy of Audiology, 19*, 135-146.

Stuart, A., Zhang, J., & Swink, S. (2010). Reception thresholds for sentences in quiet and noise for monolingual English and bilingual Mandarin-English listeners. *Journal of the American Academy of Audiology, 21*(4), 239-248.

Takata, Y., & Nábělek, A. K. (1990). English consonant recognition in noise and in reverberation by Japanese and American listeners. *Journal of the Acoustical Society of America, 88*(2), 663-666.

Tun, P. A., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology and Aging, 17*(3), 453-467.

United States Census Bureau. (2005-2009). *2005-2009 American community survey 5-year estimates: Language spoken at home by ability to speak English for the population 5 years and over* (No. B16001). Retrieved from http://factfinder.census.gov/servlet/DTTable?_bm=y&-context=dt&-ds_name=ACS_2009_5YR_G00_&-mt_name=ACS_2009_5YR_G2000_ B16001&-CONTEXT=dt&-tree_id=5309&-redoLog=true&-geo_id=01000US&-geo_id= 05000US48303&-search_results=01000US&-format=&-_lang=en

University of Tampere. (n.d.) *AV3F English public speaking class reference files*. Retrieved from http://www.uta.fi/FAST/AV3F/rainbow.html

Van Engen, K. J., & Bradlow, A. R. (2007). Sentence recognition in native- and foreign-language multi-talker background noise. *Journal of the Acoustical Society of America, 121*(1), 519-526.

Von Hapsburg, D., Champlin, C. A., & Shetty, S. R. (2004). Reception thresholds for sentences in bilingual (Spanish/English) and monolingual (English) listeners. *Journal of the American Academy of Audiology, 15*, 88-98.

Voyager universal literacy system: Teacher training manual. (2003). Dallas, TX: Voyager Expanded Learning.

Zabel, H., & Tabor, M. (1993). Effects of soundfield amplification on spelling performance of elementary school children. *Educational Audiology Monograph, 3*, 5-9.