ABSTRACT: Purpose: Two studies were conducted to investigate the effects of classroom noise on attention and speech perception of typically developing children who are listening through their second language (L2) as compared to their English-only-speaking (EO) peers. Method: Study 1 measured children’s on-task behavior during instructional activities with and without soundfield amplification. Study 2 measured the effects of noise (+10 dB signal-to-noise ratio) using an experimental English word recognition task. Results: Findings from Study 1 revealed no significant condition (pre/postamplification) or group differences in observations in on-task performance. Main findings from Study 2 were that word recognition performance declined significantly for both L2 and EO groups in the noise condition; however, the impact was disproportionately greater for the L2 group. Clinical Implications: Children learning in their L2 appear to be at a distinct disadvantage when listening in rooms with typical noise and reverberation. Speech-language pathologists and audiologists should collaborate to inform teachers, help reduce classroom noise, increase signal levels, and improve access to spoken language for L2 learners. KEY WORDS: bilingual learners, speech perception, noise.
early elementary grades (e.g., Shield & Dockrell, 2003). Yet, extensive evidence indicates that children need a favorable signal-to-noise ratio (SNR) for full understanding of the spoken message (e.g., Elliott, 1979; Johnson, 2000).

Classrooms for young learners in older urban schools may be even noisier than those in other schools. The single most significant source of noise in schools is the heating, ventilation, and air-conditioning (HVAC) system; the second most common source is noise from traffic on adjacent highways (Acoustical Society of America [ASA], 2002; American National Standards Institute [ANSI], 2002). Many older urban schools have high ceilings, hard walls and ceilings, and older HVAC systems that contribute to greater noise levels (Knecht, Nelson, Whitelaw, & Feth, 2002). Knecht and colleagues found that unoccupied classrooms had noise levels as high as 65 dBA. Further, classrooms that were occupied by active learners are considerably noisier (10 to 20 dBA) than unoccupied classrooms (e.g., Bess, Sinclair & Riggs, 1984). Many busy classrooms can thus be assumed to have noise levels of 70 dBA and higher, resulting in SNRs that are difficult for all children. Although a 1995 survey of teachers conducted by the U.S. General Accounting Office found no direct relationship between the age of a school and its acoustics, poor acoustics due to classroom noise was the number one complaint of teachers in aging schools. A national task force has recently introduced a new standard supported by ANSI (2002) that specifies maximum background noise levels for new schools based on the extensive literature in that area. The standard recommends maximum classroom noise levels of 35 dBA (and 55 dB C) so that young children can obtain SNRs of +15 dBA or better for adequate listening and learning.

In addition to noise and developmental factors, children’s experience with a specific language also may affect their ability to make sense of incoming speech. Lindblom (1990) discussed two sources of information that affect mutual understanding between speaker and listener: signal-dependent information and signal-independent information. Signal-dependent information refers to the integrity and availability of the acoustic signal. In contrast, signal-independent information relates to what the listener brings to the task, such as linguistic knowledge and familiarity with the topic or content of the spoken message. Linguistic knowledge includes familiarity with meaningful distinctions at the semantic, syntactic, morphological, and phonological levels (Lindblom, 1990; see Hustad, Jones, & Dailey, 2003, for review). The ability to perceive and relate fine-grained shifts in the acoustic signal to meaningful differences at the various linguistic levels lies at the heart of early literacy. Indeed, research in the past decade has consistently supported strong links between oral and written language skills (e.g., Stackhouse & Wells, 1997). Typically developing English-speaking children rely on their keen knowledge of spoken language, built up over time from early infancy through the preschool years, to learn the sophisticated sound-meaning mapping that is then translated into written language in the elementary school grades.

Given these strong links between oral and written language skills, we can hypothesize that children in the United States who are learning languages other than English during the preschool years cannot rely on their cumulative oral language experience as a bridge to literacy to the same degree as their monolingual English-speaking peers. This is particularly the case when primary instructional activities are in English rather than the home language. For example, children who acquire Spanish as their first or primary language (L1) at home and learn spoken and written skills simultaneously in English, their L2, may rely much more on explicit information contained in the acoustic signal for comprehension. This increased reliance on the acoustic signal, rather than on previous linguistic experience in English, may place an additional burden on L2 learners in noisy classrooms.

Indeed, research with adult listeners suggests that even with fully developed auditory processing systems, the adults’ ability to listen in an L2 is negatively impacted by the presence of background noise (e.g., Bahrick, Hall, Goggin, Bahrick, & Berger, 1994; Mayo, Florentine, & Buus, 1997; Nabelek & Donahue, 1985; van Wijngaarden, Steeneken, & Houtgast, 2002). For example, Bahrick and colleagues tested 801 native Spanish-speaking individuals who began to learn English as their L2 after the age of 10, primarily as adolescents or young adults. Participants’ length of residence in the United States, used to index experience with English, ranged from 4 months to 50 years. All participants were also highly literate in Spanish, having received several years of instruction in their native countries before immigration. A primary objective of the Bahrick et al. study was to determine participants’ “dominant” or stronger language as a test of the critical period hypothesis for L2 learning. Parallel versions of experimental tasks were administered in Spanish and in English. For present purposes, of interest is the discrepant performance on the single task that assessed auditory language processing relative to visually presented language tasks. These researchers developed an experimental task they called the “Oral Comprehension Dominance Test.” In this task, participants listened to spoken sentences in either Spanish (L1) or English (L2). These sentences were presented against a background of white noise (the SNR was stated by the authors as approximately 2:1, with no additional details about signal and noise levels reported). The remaining three tasks were all text based and were presented visually. Bahrick and colleagues found that, as length of residence in the United States increased, performance on the three text-based tasks equaled that of the monolingual English-speaking control group. In contrast to the strong performance in English on these visual language tasks, performance by the adult bilingual group on the oral comprehension dominance test in English (i.e., listening to sentences in noise) was lower than that of the English-only control group (Bahrick et al., 1994). Similarly, Mayo and colleagues (Mayo et al., 1997) found that monolingual and early bilingual participants (operationally defined as L2 learning before age 6) outperformed late bilinguals on the Speech-in-Noise (SPIN) test.

Thus, because of both developmental and language-specific issues, there are good reasons to believe that school-age children learning through their L2 may be at double
jeopardy with respect to the effects of classroom noise. This is an important consideration because nationally, urban schools report significant numbers of students who speak languages other than English at home. Approximately 10% (28 million) of individuals counted in the 2000 U.S. Census were not born in this country. By 2010, it is estimated that one of every five schoolchildren will be a recent immigrant to the United States, and the majority of these children will likely acquire languages other than English at home (U.S. Bureau of the Census, 2000). Specifically, in Minnesota, more than 24% of students in the largest school district speak other languages at home and are classified as English-language learners (ELLs) (Minneapolis Public Schools, 2003); the second largest school district has 41% ELL students (St. Paul Public Schools, 2003).

Few studies have investigated the impact of noise on speech perception in school-age children acquiring English as their L2. Crandell and Smaldino (1996) used an American version of the Bamford-Koval-Bench (BKB) Standard Sentence Test (Kenworthy, Klee, & Tharpe, 1990) to assess speech perception in 20 native Spanish speakers who began learning English before age 2 and 20 monolingual English speakers. Participants ranged in age from 8 to 10 years. In the BKB Standard Sentence Test, children are asked to repeat syntactically and semantically balanced sentences in English. Fifty key words are scored for accuracy. Crandell and Smaldino presented these sentences with varying levels of competing noise (with SNR ranging from +6 dB to –6 dB). All children were tested individually in a sound booth with monaural stimuli presentation. The primary study finding was that monolingual children outperformed the bilingual children at all noise levels. Of note was that as noise increased, so did the performance gap between these two groups of children (Crandell & Smaldino, 1996). The current study revisits this important issue, using different dependent variables in an effort to extend this earlier work.

The impact of noise on listening skills can be determined in different ways. The current study employed two distinct methods: observation of on-task behavior and a direct measure of speech perception using a word recognition task. Study 1 used the systematic observation of children’s performance during instructional activity as the critical dependent variable to index potential changes in students’ on-task behavior before and after the introduction of soundfield amplification. Classroom observations are considered an important component in communication assessments, particularly for linguistically diverse students (e.g., Goldstein, 2000). Previous studies have found improvement in on-task performance for some children following the introduction of soundfield amplification relative to a baseline condition of no amplification. Palmer (1998) reported a greater change in off-task behavior for several younger children (kindergarten and first grade) in her study than for the 2 second graders who were participants in that study. Eriks-Brophy and Ayukawa (2000) also observed the behavior of 3 second graders with attention or hearing problems. Two of the 3 second graders showed improvements in classroom behavior following amplification. These 2 participants had known hearing and/or attention deficits; the third participant did not.

Study 2 used a forced-choice word recognition task to directly measure selected aspects of speech perception in order to replicate and extend the findings of Crandell and Smaldino (1996). In that study, bilingual children were more adversely affected by background noise for sentence repetition than were monolingual children. In the current Study 2, children heard a word presented in a sound field, then indicated on their response form one of two pictures that best corresponded to this spoken word. In sentence repetition tasks, participants can rely on their syntactic knowledge to fill in gaps in the acoustic signal. In contrast, in the current word recognition task, children were forced to attend to the phonemic contrasts in the spoken signal to distinguish between word pairs that sounded very similar but had very different semantic properties. For example, children saw a picture of a rake and a lake. Participants then heard the word “rake” and were instructed to choose the picture that best matched this spoken word. One set of words included phonemic contrasts that are generally found in English and Spanish, dialectal variations not withstanding. However, because learning an L2 often involves learning phonemic contrasts that do not occur in the native language, we developed a second list of word/picture pairs that included sounds that are largely used contrastively in English but not in Spanish. For example, “s” and “z” (as in bus and buzz) are not used contrastively in Spanish.

The general purpose of this investigation was to determine the effects of noise on attending and speech perception skills in children learning through their L2, relative to their monolingual peers. In Study 1, students were observed for their on-task behaviors in a baseline condition (no amplification) and following the installation of a classroom soundfield amplification system. It was hypothesized that children learning through their L2 might show a higher incidence of off-task behaviors during instructional periods without amplification as well as greater changes in on-task behavior rates following installation of soundfield amplification. In Study 2, students were tested for their ability to discriminate between very similar sounding pairs of words in quiet and in noise. The pairs of words differed by speech sounds that were either contrastive in both English and Spanish (E-S) or contrastive largely in English only (E-only). We hypothesized that although all children would be adversely affected by background noise for all words, the greatest detrimental effect of the noise would be on L2 children listening to English-only contrasts in noise.

METHOD

Participants and Classroom Setting

Second-grade students from three classrooms in a Minneapolis public school participated in the project. The school has a significant enrollment of children who speak Spanish in their homes (approximately one third of the second graders come from Spanish-speaking homes) and offers an active bilingual education program. The majority
of these children are from families who have immigrated to Minnesota from Mexico or Central America. The bilingual students spend the morning in regular classrooms learning math, science, and social studies in English. In the afternoons, they study reading, spelling, and language in Spanish.

Participants were 22 second-grade students from three different classrooms. Characteristics of the classrooms are provided in Table 1. The school was an older, urban school with hard floors, high ceilings, and numerous tall windows looking out on to a busy street. Classrooms had been recently renovated, but teachers reported that noise levels were occasionally higher than desirable. Of the 22 participants, 12 students participated in classroom observations (Study 1) and all 22 students participated in the speech perception test (Study 2). Students included 7 monolingual English-only-speaking children (EO group) and 15 children who spoke Spanish in the home as their L1 and learned English as their L2 (L2 group). All children in the L2 group were classified as ELLs based on school records. All children in the L2 group had a minimum of 1 year of experience with English in the school setting, and most had been in the same educational setting for a minimum of 2 years. Participants in both groups were screened for normal hearing sensitivity (American Speech-Language-Hearing Association [ASHA], 1996). All participants were functioning at grade level in a regular second-grade class. None of the participants was eligible for additional services other than the bilingual services outlined above. Data collection for Study 1 was completed before data collection for Study 2. Procedures and stimuli specific to each study are presented separately.

Study 1: Classroom Observations

Second-grade teachers and the school speech-language pathologist (SLP) were concerned about excessive noise levels in their recently renovated classrooms. Because of that concern, regular noise measurements were made in the classrooms and arrangements were made for soundfield amplification systems to be used in the rooms on a trial basis. An experienced audiology student research assistant made regular sound level measurements and observations of on-task behavior of 12 students. All observations were made in the regular classrooms in which English was the language of instruction. Ten classroom observations were made before installation of the soundfield amplification system, and five observations were made following system installation. Observations were conducted only when the classroom activity centered on a teacher-led learning exercise. The language status of the children was unknown to the research assistant observer. It was later determined that 4 students were classified as EO and 8 as L2. Of those, 3 EO students and 7 L2 students completed the before and after observations. Two students (1 from each group) transferred out of the classes before data collection was completed. Their data were not included.

The observer first measured sound levels in the room at the time of observation and noted the activity going on in the class. For noise measurements, she used a Radio Shack digital sound level meter (#33-2055) and noted measurements in dBA and dBC. She then monitored each student’s behavior for approximately 10 s and classified that period of time as primarily on task (+) or off task (−). Behaviors that were considered on task included eye contact in the direction of the speaker, initiation of appropriate responses toward the speaker, and following directions (after Palmer, 1998, and Eriks-Brophy & Ayukawa, 2000). Behaviors that were considered off task included eye contact away from the speaker, inhibition of conversations apart from the speaker, and noncompliance in following directions. Each student’s behavior was monitored for a 10-s period and classified. Then the next student’s behavior was similarly monitored and classified. The observer continued to monitor on-task behavior for approximately 20 min, obtaining an average of 20 classifications per student. The noise was again measured, and the observation session was complete. On the first day of observation, two observers monitored children in one classroom and compared their responses for reliability. They found 95% interobserver reliability.

Single-speaker soundfield FM amplification systems (Lightspeed®, Lightspeed Technologies) were installed in each of the second-grade classrooms during the sixth week of the study. The speaker location was determined jointly by consultation between the SLP, the teacher, and a university audiologist (the first author). Teachers were trained in microphone use, troubleshooting, and maintenance. The SLP and audiologist checked each system regularly during the first week after installation. The SLP provided continued support for the teachers and contacted the manufacturer for repairs when necessary. Results of Study 1 are reported in terms of percentage of on-task behavior for each group before and after installation of the soundfield amplification system.

Table 1. Classroom characteristics in Study 1.

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Dimensions</th>
<th>Flooring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 1</td>
<td>17</td>
<td>23.5' × 38.5'</td>
</tr>
<tr>
<td>Room 2</td>
<td>20</td>
<td>23' × 38.5'</td>
</tr>
<tr>
<td>Room 3</td>
<td>17</td>
<td>23' × 27.5'</td>
</tr>
</tbody>
</table>

Note. All three rooms had 12-foot ceilings.

1 Sound levels were measured using both A-weighted and C-weighted decibel scales, as recommended by ANSI S12.60-2002. A-weighted scales simulate the response of the human ear, in that the contribution of the lowest frequencies (such as those <200 Hz) are attenuated because they are inaudible to human listeners. C-weighted scales attenuate the low frequencies very little and are similar to linear sound pressure level measurements. ANSI S12.60 recommends that sound levels in unoccupied classrooms should not exceed 35 dBA or 55 dBC.
Study 2: Speech Perception With and Without Noise

The picture-word identification task was a spoken, two-choice recognition task in which children heard a word in English and then chose which of two pictures best fit the word. Two lists of word stimuli were developed (see the Appendix). Each list consisted of 13 word pairs that were very similar in the way they sounded. Word pairs in the first list, control words, emphasized sounds that are largely present in both Spanish and English, such as tea/hwo (S–E phoneme contrasts). Word pairs in the second list, E-only phoneme contrasts, again consisted of similar word pairs that sound very similar, but here the contrasting sounds typically occur in English but not in Spanish (such as vote/boat and pin/pen). We used a very general classification system to develop our word lists and did not consider allophonic or dialectal variations (refer to Goldstein, 2001, for overview).

Given the known effects of frequency on word recognition, it was possible that differences in word frequency could contribute to performance differences, as opposed to the types of sound contrasts used in our word lists. We determined word frequency for our stimulus items using English (as opposed to Spanish) child corpora data (Carroll, Davies, & Richman, 1971). A two-tailed t test indicated no significant differences in the mean frequency between control and experimental word lists (p = 0.4). Stimuli were recorded directly to a hard disk by a native English-speaking adult female and were normalized for amplitude using CoolEditPro© (Syntrillium, 2002). Auditory stimuli were saved in quiet form and also were later mixed with multitalker babble at +10 dB SNR. Stimuli were edited and made into one practice list and two test lists with accompanying picture forms. Black and white line-drawn pictures were selected to match each stimulus word (Bates et al., 2003; Snodgrass & Vanderwart, 1980).

Two parallel test forms (labeled A and B) were generated that contained 13 pairs of pictures. Test items were randomly selected from each pair. Control and experimental items were interspersed throughout the test forms in random order. Response forms that included these picture pairs arranged in numbered columns were given to each of the 26 items individually via live voice. Students were instructed to listen to each word and to circle the corresponding picture on their practice response form. The experimenter circulated throughout the room during practice, making sure that all students were 100% accurate. Words corresponding to more complex pictures (such as vote, tan, and cheep) were discussed so that students could match the picture with the word.

Mean accuracy was obtained for each child according to condition (noise or quiet) and stimulus type (S–E contrasts or E-only contrasts). The response was a forced choice from one of the two possible responses so that chance performance across conditions and stimulus types was 50%. An item analysis was also conducted to determine if particular items were more difficult for both groups, in both quiet and noise conditions.

RESULTS

Study 1: On-Task Observations

Classroom noise levels ranged between 54 and 67 dBA (59 to 67 dBC) during the 10 days that observations were made. These noise levels were obtained while the class was engaged by the teacher during teacher-directed activities. The measurements were made near the back of the room where the observer sat. These values are very similar to previously reported levels of noise in occupied classrooms (e.g., Eriks-Brophy & Ayukawa, 2000). Direct measures of classroom SNR were made on one occasion during an activity that was typical of classroom activities during observation periods. Measurements showed that the SNR was increased by an average of 3 dB at the observer’s location when the amplification system was on.

The mean on-task performance ratings and standard deviations for EO and L2 learners before and after soundfield amplification are shown in Table 2. There were no significant differences noted in classroom on-task behavior between groups or between before and after observation periods. The EO group was on task 78% of the time before amplification and 75% after amplification. The L2 group was on task 79% of the time before amplification and 78% of the time after amplification. None of these differences was significant. The teachers were judged to be quite effective at maintaining children’s attention with and without the soundfield amplification system. Effective strategies used by teachers to maintain students’ attention included walking around the room, directing frequent questions to the class, and making eye contact with individual students.

Study 2: Speech Perception With and Without Noise

Individual raw scores across stimuli and conditions ranged from a low of six (46%) to a high of thirteen (100%). All mean group scores were significantly above...
Table 2. Behavioral observations of on-task behaviors for the English-only-speaking (EO) group and the second-language (L2) group in Study 1.

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>EO group</td>
<td>78%</td>
<td>20%</td>
</tr>
<tr>
<td>L2 group</td>
<td>79%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Note. The mean and standard deviations for the proportion of time classified as “on task” is shown for observations before and after installation of a soundfield amplification system.

chance performance (50%). Raw scores were converted using the arcsine transformation \( y = \text{arcsine}(\sqrt{N \times 100}) \) where \( N \) is the percentage of correct scores and \( y \) is the transformed data in order to stretch out both ends of the data so that differences near ceiling and floor effects may be seen. Mean accuracy scores for each group in noise and quiet conditions for each stimulus type are summarized in Table 3. Performance declined in noise for both groups, although this decline was significantly greater for the L2 group than for the EO group (see statistical analysis below). Scores were also lower for the E-only contrasts than for the S–E contrasts \((p < .05)\). The performance decrements due to the stimulus type (control vs. experimental) and to the presence of the noise are shown in Table 4 for both groups of students. Note that the groups show similar performance decrements for control versus experimental stimuli. The L2 group, however, shows a mean performance decrement that is more than four times the size of the EO group decrement.

To determine the effect of noise on group performance, transformed data were entered into a 2-way mixed analysis of variance (ANOVA) with group (EO and L2) as the between-subjects factor and condition (quiet and noise) as the within-subjects factor. There were main effects of group, \(F(1, 20) = 7.147, p < .015, d = 0.57\), reflecting the greater accuracy for the EO group, and condition, \(F(1, 20) = 5.4, p < .031, d = 0.48\), indicating the relatively better performance for both groups on the stimulus pairs that used phonemes present in both Spanish and English. There was no Group \(\times\) Condition interaction. Results for the effect of stimulus type on group performance, collapsed across noise conditions, are shown in Figure 2.

Results of an item analysis for each pair of stimulus words for EO and L2 learners in quiet and noise conditions are included in Table 5. For both participant groups, the largest numbers of errors occurred for the stimulus pairs bowl/bone and ten/tan. Accuracy for the bowl/bone pair was 57% for the EO group in quiet and 43% in noise; accuracy for the L2 group was 73% in quiet and 60% in noise. For the ten/tan pair, EO accuracy was 71% in quiet and noise; L2 accuracy was 47% in quiet and 40% in noise. These two stimulus pairs accounted for approximately one third of the total errors but were proportional across groups and noise conditions. A reanalysis of the data with these items omitted did not change the presence or direction of the main and interacting effects that were reported previously. Other errors were distributed evenly among stimulus items in quiet. Children in the L2 group scored 80% or less on the following items in noise: ball/wall, sheep/ship, boat/vote, pen/pin, bat/bath, and buzz/bus. Interestingly, the EO group was only 57% accurate in discriminating between pen/pin in noise.

Table 3. Summary scores for groups, conditions, and stimulus type in Study 2.

<table>
<thead>
<tr>
<th></th>
<th>Quiet</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S–E contrasts</td>
<td>E-only contrasts</td>
</tr>
<tr>
<td>EO group</td>
<td>97% (4%)</td>
<td>95% (4%)</td>
</tr>
<tr>
<td>L2 group</td>
<td>96% (5%)</td>
<td>91% (14%)</td>
</tr>
</tbody>
</table>

Note. Mean percentage correct and standard deviations (in parentheses) for each group are shown for quiet and noise conditions. S–E refers to stimulus pairs that differed by phonemic contrasts that are present in Spanish and English; E-only denotes stimulus pairs that differ by phonemic contrasts that are present in English but not Spanish.
Discussion

Two studies were conducted to determine if processing information in English under adverse listening conditions had a greater effect on second-grade students who were learning English as an L2 as compared to their monolingual EO classmates. Children in the L2 group were all native speakers of Spanish. The adverse listening condition of interest was the presence of noise. In Study 1, the language to be processed was the teacher’s voice during instructional activities in English. The impact of classroom noise was inferred through systematic observation of children’s attending behaviors before and after installation of soundfield amplification systems. The underlying idea here is that difficulty in processing language will result in student inattention and observable off-task behaviors. In Study 2, the language to be processed consisted of isolated words. In this study, the impact of noise on speech perception was measured directly as children selected one of two pictures that best matched a spoken word, with pictures depicting words that sounded very similar. In the absence of other auditory or visual information, children were forced to attend to only the linguistic form that was presented either in quiet or in the presence of competing noise. The following sections present the results from each of these studies, as well as the implications from these combined studies for intervention in the educational setting.

Behavioral Observations With and Without Soundfield Amplification

In contrast to the original hypothesis, results from Study 1 revealed no significant differences in on-task behavior between L2 learners and their monolingual peers, and no difference between pre- and postamplification measures. Previous reports (e.g., Eriks-Brophy & Ayukawa, 2000; Palmer, 1998) indicated that some children show improved classroom attention skills when soundfield amplification systems are used. In the current study, no such trend was found for either the EO or the L2 students. Why was no improvement in on-task behavior observed here following the installation of amplification systems? There are a number of possible reasons. First, previous studies found the greatest benefit from soundfield amplification to be for those children who had been identified as having significant behavioral or attentional problems in the classroom (Eriks-Brophy & Ayukawa, 2000; Palmer, 1998). None of the children in the current study was identified as having attention problems. Indeed, children from both groups were considered by their teachers to be engaged, attentive classroom participants during anecdotal poststudy interviews. A second possible reason for the stable measures of attention across listening conditions is that observations of on-task behavior may be less sensitive to differences in typical learners at this developmental level. For example, Palmer (1998) reported a greater change in off-task behavior for the younger children.

Table 4. Response decrement across conditions and stimuli.

<table>
<thead>
<tr>
<th>Group</th>
<th>Quiet–Noise</th>
<th>Control–Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO</td>
<td>2.2 %</td>
<td>4.4 %</td>
</tr>
<tr>
<td>L2</td>
<td>10.5 %</td>
<td>5.9 %</td>
</tr>
</tbody>
</table>

Note. Mean difference scores.

Figure 1. Mean percentage correct scores are shown for EO and L2 groups for items presented in quiet and in noise. L1 learners are shown as dark bars; L2 learners are shown as light bars. Error bars indicate one standard error. Scores were collapsed across stimulus type.

Figure 2. Mean percentage correct scores are shown for EO and L2 groups for experimental (E-only contrasts) and control (S–E contrasts) words. The S–E minimal word pairs differed by a sound that is used contrastively in both English and Spanish. The E-only word pairs differed by a single phoneme that is largely used contrastively in English but not Spanish. Error bars indicate one standard error. Scores were collapsed across noise conditions.
A third potential reason for the lack of observed behavior change across conditions is that the measures used to qualify performance in this study were not sufficiently fine grained to reflect changes in behavior. Eriks-Brophy and Ayukawa (2000) observed the behavior of 3 second graders with attention or hearing problems. Two of the three second graders showed improvements in classroom behavior, but the only significant differences found (pre- and post-amplification) were related to body orientation. The current study did not measure body orientation but rather used a binary classification system to consider a cluster of behaviors as either “on” or “off” task. It should be noted, however, that the average rates of attention and range of on-task behaviors for the typically developing children included in the Eriks-Brophy and Ayukawa study were very similar to those reported here for both the L2 and EO groups.

Fourth, the type of soundfield amplification used in these classrooms could have affected the outcome. The single-speaker system provided approximately 3-dB improvement in the SNR at the teachers’ user settings. The teachers preferred to set the gain relatively low so that their voices did not project into the adjacent rooms and so that they did not have to worry about feedback in the system. It is possible that a multi-speaker system set at a higher gain level might have provided additional benefit. If a teacher’s primary amplification objective is improving children’s on-task behaviors, a more powerful soundfield amplification system might be recommended.

A final reason for the relatively stable on-task performance across listening conditions for current study participants may be the pedagogical methods employed by the classroom teachers. Children were observed in three different classrooms with three different teachers. During these observations, teachers consistently employed effective strategies for engaging students in the instructional activities. As a result, off-task behaviors were low overall considering, of course, the general level of attentiveness expected of second-grade children. Interestingly, despite the lack of significant differences in on-task performance for children in Study 1, teachers were very enthusiastic about the soundfield amplification systems. They described ways in which they used the systems selectively to gain students’ attention. Teachers also used the systems extensively for reading aloud to the larger group so that they were able to use a relaxed voice. All three teachers continued to use the soundfield systems well beyond the duration of the study. Two of the systems are still in use by the second-grade teachers. (The third teacher has changed assignments and no longer teaches second grade.) Other teachers from that school have requested similar systems and are using them primarily for alleviation of chronic voice fatigue.

In summary, there were no differences in observed on-task behavior across listening conditions. Moreover, it appears that the L2 learners in this study were engaged in

<table>
<thead>
<tr>
<th>Stimulus pairs</th>
<th>EO Quiet (n = 7)</th>
<th>EO Noise (n = 7)</th>
<th>L2 Quiet (n = 15)</th>
<th>L2 Noise (n = 15)</th>
<th>Totals (n = 44)</th>
</tr>
</thead>
</table>
Speech Perception in Quiet and in Noise

Study 2 measured the impact of noise on children's ability to discriminate between word pairs that sounded very similar. Word pairs differed by sounds that were either contrastive in both Spanish and English (S–E) (e.g., boy/toy) or contrastive in English only (E-only) (e.g., boat/vote). Recall that before testing, all children participated in a training session during which they demonstrated mastery of both test stimuli and procedures. Participant performance during this training phase increases our confidence in attributing any between-group differences in performance during the test phase to the variables of interest—noise and stimulus items—rather than to other factors that were not systematically controlled.

Consistent with the study hypothesis, response accuracy for both the L2 and EO groups was significantly lower in noise relative to quiet. This result is also consistent with previous studies of speech perception in noise (Elliott, 1979; Johnson, 2000). The critical finding, however, was that noise had a greater impact on the L2 group's performance. Indeed, collapsing across stimulus types, the average decline in performance accuracy for processing words in noise was more than four times greater for the L2 group (10.5%) than for the EO group (2.2%). The type of stimuli to be processed was also important. For example, mean L2 group performance was high (96%) for control words (containing phonemes that are contrastive in both Spanish and English) in the quiet condition. However, L2 group accuracy was lowest (79%) in noise on the word list constructed to highlight sounds contrastive in English but not in Spanish. Although the item analysis (shown in Table 5) generally supports this interpretation, there are some clear limitations. For example, the list of control words focused on stimulus pairs that contained sounds that would be largely consistent with the experience of both English and Spanish speakers. However, some sounds in this list (such as the "r" sound in rake contrasted here with lake and the "oy" sound in boy and toy) are not sounds in Spanish (Goldstein, 2001). Therefore, these particular items and others may have been additionally difficult for L2 learners than some of the other control pairs. Future studies may control for this difficulty more carefully. It is also interesting that we found that vowel perception may be quite difficult for children learning English as an L2 (e.g., ten/tan). This finding is generally consistent with previous work investigating vowel perception in adult L2 learners (e.g., Flege, MacKay, & Meador, 1999). However, we also found that EO children had difficulty perceiving some vowel contrasts (ten/tan and pen/pin). In the current study, there were very few items specifically contrasting the perception of vowels (as opposed to consonants). Systematic study investigating vowel perception in native and nonnative English-speaking children is needed to further inform this issue.

In addition to these differences in mean group performance, there was also greater variation within the L2 group as compared to the EO group. In the quiet condition, EO learner scores ranged from 92% to 100% correct; L2 learner scores ranged from 71% to 100% correct. For the noise condition, EO scores ranged from 77% to 100% correct; L2 learner scores ranged from 54% to 100% correct. This type of performance variability is consistent with that found in a relatively homogeneous group of similar-aged Spanish-speaking children learning English as an L2 using other measures of language processing (e.g., Kohnert, 2002). These results are also consistent with those of Crandell and Smaldino (1996), who noted significantly larger variability on their speech recognition in noise task among the L2 learners in their study as compared to their EO peers. It will be important for future studies to systematically investigate factors that may contribute to this within-group variability. These factors affecting individual performance may include proficiency in English as well as efficiency in processing nonlinguistic, as well as linguistic, information (cf. Kohnert & Windsor, 2004).

The findings of significant between-group differences in accurately perceiving words in noise relative to quiet is all the more impressive in light of this considerable within-group variability combined with the relatively small number of children included in each group (EO = 7; L2 = 15). We believe this speaks to the scale of the disproportionate impact of noise on children learning through their L2.

CLINICAL IMPLICATIONS

There is a developmental disadvantage for listening in noise that is experienced by all preadolescent learners (e.g., Johnson, 2000). Yet, evidence from Knecht et al. (2002) and others suggests that unfavorable SNRs are common in American classrooms. The primary finding from the current study is that in noisy classrooms in which the target voice occurs at +10 dB SNR or less, processing linguistic information in English will be significantly more challenging for typically developing L2 learners as compared to their monolingual peers. These combined sources thus suggest that linguistically diverse children receiving primary instruction in English in typical classroom conditions do, in fact, experience double jeopardy with respect to the negative impact of noise.

The implication from these findings is that we should increase the saliency of the acoustic signal, particularly during those activities that are most closely related to language arts, to promote language and literacy skills in L2 learners. This concept was at the heart of the recent ANSI standard for classroom acoustics (ANSI, 2002), which applies to new and renovated classroom spaces. Classrooms that meet the standard will provide SNRs that will be more favorable than +10 dB (that was shown to be insufficient here for L2 learners) and should allow optimal listening conditions for all students. Unfortunately, current classrooms often fall short of this goal, and teachers, audiologists, and SLPs often must work with students in these less favorable
acoustic conditions. Toward this end, we suggest that educational audiologists consult with classroom teachers on three interconnected aspects of sound management in the instructional setting: (a) to recognize the unique combination of acoustic and learner characteristics present in their classrooms; (b) to develop ways to reduce noise during instructional activities; and, if necessary, (c) to raise the level of the target signal, particularly during literacy-based activities.

We first recommend that school professionals should identify sources of noise inside their classrooms, paying particular attention to those rooms containing students learning through their L2 as well as children with hearing loss, attention deficits, and language-learning problems. Some noise can be eliminated easily, such as noise from optional equipment like fish tanks, computers, and projectors (see Knecht et al., 2002). More commonly, noise may arise from in-room HVAC systems. Other noise may arise from outside the building through substandard windows or from outside the classroom through walls and doors leading to hallways and doors leading to adjacent spaces (Nelson, Soli, & Seltz, 2002). Noise from chairs scraping on tile floors can be controlled by using pads or used tennis balls on the chairs’ metal feet. In some cases, the source of the noise may be controlled; in other cases, an inexpensive solution may be workable. (See ASA, 2000, as well as the annexes to ANSI Standard S12.60, for some guidance in this area.) Our second recommendation is to further reduce noise in these classrooms during teacher-led instructional activities. Windows may be closed to traffic noise, HVAC systems and computers may be turned off, and doors or partitions may be closed during active listening times. Finally, we recommend increasing the level of the desired signal by reducing the distance between the speaker and the students and through judicious use of soundfield amplification systems. On the basis of the results of this study and others, we would not expect soundfield amplification to automatically improve all students’ on-task behavior nor to increase speech recognition to full understanding. Nevertheless, it may provide for a stronger signal that will improve the effective SNR.

These results highlight that with current typical classroom acoustic conditions (SNRs of +10 dB and less), some children can be expected to experience significant decrements in understanding. In particular, children learning in their L2 appear to be at a distinct disadvantage when listening in rooms that are typical of American classrooms. In light of the large numbers of L2 children in schools, classroom teachers, SLPs, and audiologists should collaborate to intervene, reduce classroom noise, increase signal levels, and thus improve access to spoken language by L2 learners.

ACKNOWLEDGMENTS

Support for this research was provided by the University of Minnesota to the third author from the Bryng Bryngelson Communication Disorders Research Fund for graduate students. Additional funding was provided by Grant R03 DC05542 (titled Cognitive-Linguistic Processing in L1 and L2 Learners) to the second author from the National Institute of Deafness and Other Communication Disorders and by the University of Minnesota (McKnight Land-Grant Professorship). We are grateful to the administration, teachers, and students at Jefferson Elementary School for their participation in this study and to Edward Carney for assistance with data analysis.

REFERENCES


Kenworthy, O., Klee, T., & Tharpe, A. (1990). Speech recognition ability of children with unilateral sensorineural hearing loss...


Received March 15, 2004
Revision received July 6, 2004
Accepted October 22, 2004
DOI: 10.1044/0161-1461(2005/022)

Contact author: Peggy Nelson, 115 Shevlin Hall, 164 Pillsbury Drive Southeast, University of Minnesota, Minneapolis, MN 55455. E-mail: nelso477@umn.edu

---

**APPENDIX. STIMULUS PAIRS**

<table>
<thead>
<tr>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>bowl/bone</td>
<td>mouse/mouth</td>
</tr>
<tr>
<td>B/C</td>
<td>keys/kiss</td>
</tr>
<tr>
<td>cane/cake</td>
<td>ten/tan</td>
</tr>
<tr>
<td>dish/fish</td>
<td>sheep/ship</td>
</tr>
<tr>
<td>boy/toy</td>
<td>glove/globe</td>
</tr>
<tr>
<td>lake/rake</td>
<td>boat/vote</td>
</tr>
<tr>
<td>toast/toes</td>
<td>pen/pin</td>
</tr>
<tr>
<td>tea/two</td>
<td>watch/wash</td>
</tr>
<tr>
<td>hose/nose</td>
<td>bat/bath</td>
</tr>
<tr>
<td>hair/chair</td>
<td>B/V</td>
</tr>
<tr>
<td>cap/cup</td>
<td>buzz/bus</td>
</tr>
<tr>
<td>ball/wall</td>
<td>dime/time</td>
</tr>
<tr>
<td>fan/can</td>
<td>cheep/sheep</td>
</tr>
</tbody>
</table>