Functional Listening Evaluation Performance in Children with Reading Difficulties

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Listening to a degraded speech signal over time can interfere with language development and learning in children with both language and reading disorders. Some may benefit from modifications that improve access to speech in the classroom. The Functional Listening Evaluation (FLE; Johnson & Von Almen, 1997), developed for assessing classroom listening ability in children with hearing impairment, examines how noise, distance and visual input may affect speech recognition in school. The FLE might also be useful in demonstrating the need for particular accommodations in children with normal hearing who experience reading difficulties. The FLE was administered to 41 children, aged seven to ten, who were diagnosed with language impairments affecting reading. The Fisher's Auditory Problems Checklist (Fisher, 1985) was given to participants' parents to differentiate children with and without listening difficulties. Using BKB sentences, speech recognition scores were obtained for both groups. When key-word scoring was applied, scores were high overall for all participants. With more rigorous verbatim scoring, the group with reported listening difficulties scored lower than the group without reported listening difficulties for all FLE conditions. Within each group, distant conditions yielded significantly lower scores than close conditions. Counter-intuitively, only the group without reported listening difficulties showed significantly decreased scores in the noise conditions. Absence of visual cues did not affect speech recognition for either group. The FLE was somewhat sensitive to listening difficulties noted by parents, and with modifications, may provide useful information about accommodations for children with normal hearing who are at risk academically.

Introduction

Children, even those with normal hearing, need a more favorable listening environment and a clearer signal to perceive speech optimally than do adults (Eisenberg, Shannon, Martinez, Wygonski, & Boothroyd, 2000; Elliott, 1979; Stelmachowicz, Hoover, Lewis, Kortekaas, & Pittman, 2000; Stuart, 2008). Research has identified speech perception as an area of difficulty that adversely affects not only children with hearing impairment but also children identified with both language and reading impairments with no hearing deficit (Bishop & McArthur, 2005; Bradlow, Kraus, & Hayes, 2003; Bradlow et al., 1999; Fraser, Goswami, & Conti-Ramsden, 2010; Joanisse, Manis, Keating, & Seidenberg, 2000; Mody, Studdert-Kennedy, & Brady, 1997; Nittrouer, 2002; Vandermosten et al., 2011). Many children with both language and reading impairments are known to experience difficulty perceiving and differentiating between the rapidly occurring or changing components of speech (Bishop, Adams, Nation, & Rosen, 2005; Poelmans et al., 2011; Robertson, Joanisse, Desroches, & Ng, 2009; Ziegler, Pech-Georgel, George, & Lorenzi, 2009) with subsequent underspecified phonological representations as evidenced by difficulties with processing phonological information (e.g., phonological/phonemic awareness) for word recognition (Castiglioni-Spalton & Ehri, 2003; Goswami et al., 2002; Lonigan, Burgess, Anthony, & Barker, 1998). These challenges can affect all areas of academic achievement, including the ability to read fluently and ultimately comprehend text (Wolf & Katzir-Cohen, 2001).

Importantly, many children with language and reading impairments have more difficulty with the representation of phonological information presented in noise than when presented in a quiet environment (Bradlow, Kraus, & Hayes, 2003; Snowling, 2000). A number of studies have shown that children with language and reading deficits are less accurate than children who are typically developing at repeating words or sentences when presented in noise (Boets, Ghesquière, van Wieringen, & Wouters, 2007; Boets et al., 2011; Fraser et al., 2010; Robertson et al., 2009; Vandewalle, Boets, Ghesquiere, & Zink, 2012; Ziegler et al., 2009). Vandewalle et al. (2012) measured speech perception in noise for monosyllabic words with a group of school-aged children who had both language and reading impairments. Their findings showed that these children scored significantly poorer than those who were typically developing when tested in noise; however, there was no significant difference between the groups when tested in quiet. These findings are consistent with other investigations and suggest that evaluation of speech perception in the presence of noise is more sensitive to the listening problems these children may experience (Bradlow et al., 2003; Vandewalle et al., 2012; Wible, Nicol, & Kraus, 2002). Listening in the presence of a degraded speech signal over time can be expected to interfere with language development and learning, including reading achievement. Children need to be able to perceive speech clearly in the classroom while learning to map speech sounds onto letters during the development of early reading skills (Ziegler et al., 2009).

Research has not substantiated these findings in all children with language and reading disorders. A number of studies have found that groups of children with language and reading disorders exhibit no problems with speech perception, suggesting that there are subgroups within this population (e.g., Marshall, Ramus, & van der Leyly, 2011; Ramus, 2003). The differences found in the literature may reflect the heterogeneity of this population, with children demonstrating individual variations in specific deficit areas (Bailey, Manis, Pederson, & Seidenberg, 2004; Bishop & McArthur, 2005; Marshall et al., 2011; Joanisse et al., 2000; Peterson, Pennington, & Olson, 2013). The diversity in speech perception performance found in this group makes it all the more crucial to discover the best ways to evaluate children with reading difficulties who seem to find listening a challenge. Clinicians may find that measuring speech recognition in the classroom directly will assist in identifying the individual listening needs of a particular child so that classroom accommodations and intervention strategies may be designed to provide the most benefit.

The effect of classroom acoustics on the learning of children with normal hearing who have special listening needs has received a growing amount of attention from speech/language and hearing professionals in recent years (ASHA, 2002a, 2005; Coalition for Classroom Acoustics, 1998; Crandell, Smaldino, & Flexer, 1995; Nelson & Soli, 2000). The reduction in access to the intrinsic redundancy of spoken language that occurs in adverse listening conditions (e.g., with noise, distance, and reverberation) potentially leads to decreased speech understanding for school age children in a variety of groups, including those with auditory processing disorders (APD), articulation/language disorders, learning disabilities, and those learning English as a second language (Crandell et al., 1995). Indeed, it has been suggested that all children younger than 13 years are less likely than older students or adults to understand speech well in noisy and/or reverberant conditions (Crandell & Smaldino, 2000; Elliott, 1982; Elliott et al., 1979; Klatte, Lachmann & Meis, 2010; Nabalek & Pickett, 1974; Yacullo & Hawkins, 1987). The youngest school-age children tend to be at the greatest disadvantage; for example, Jamieson and colleagues (Jamieson, Kranjc, Yu, & Hodgetts, 2004) demonstrated that kindergarteners and first graders performed significantly worse than second and third graders in understanding single words with different syllable patterns at a signal-to-noise ratio of -6 dB using noise recorded from a typical classroom. Children in these groups with special listening needs who have poorer perception of speech in noise and/or reverberation than peers with typical development would be considered at risk for academic difficulties.

Because of the widespread prevalence of poor classroom listening conditions, speech/language pathologists and audiologists have proposed that children in these diverse groups might benefit from classroom modifications that include adaptation of the physical environment to reduce noise and reverberation levels, compensatory strategies that ensure accurate reception of instruction material, and/or the use of hearing assistive technology (HAT) to increase signal-to-noise ratio (Flexer, Millin, & Brown, 1990; Flexer, Biley, Hinkley, Harkema, & Holcomb, 2002; Johnston, John, Kreisman, Hall, & Crandell, 2009: Massie & Dillon, 2006; Purdy, Smart, Baily, & Sharma, 2009; Rosenberg et al, 1999; Sharma, Purdy, & Kelly, 2012). Improving the signal-to-noise ratio and signal clarity in the classroom would be particularly important for children in the early grades because of their greater difficulty with speech perception in noise overall and the importance of establishing foundational concepts and skills for later development. Rosenberg and colleagues (1999) reported faster progress in listening and learning behaviors and skills in classrooms using sound (field) distribution systems over a 12-week period when compared to grade-matched students in unamplified classrooms. Greater benefit was shown for younger children, who had the most to gain—first graders demonstrated lower scores on the teacher rating scales than older students before the use of amplification. A higher proportion (30.88%) of the first graders in the Rosenberg et al. (1999) study was receiving special education services. A more recent investigation (Dockrell & Shield, 2012) failed to show significant gains on academic tests after six months use of sound distribution technology in a general elementary school sample; however, students in the amplified classrooms who had special educational needs did show significant improvements in academic test scores when compared with their counterparts in classrooms without sound distribution. A number of studies have indicated a significant increase in literacy skills, particularly in the areas of phonological awareness and reading comprehension, associated with the use of classroom sound distribution systems (Darai, 2000; Flexer et al., 2002; Heeney, 2007). Purdy and colleagues (2009) showed improved teacher and student ratings of classroom listening following a six-week trial use of personal frequency modulation (FM) systems at school in a group of elementary school children with reading delays; however, no significant effect of FM system use was found on scores of standardized reading tests. The authors concluded that a longer period of FM system use may be necessary to show improvement in reading test scores.

The application of HAT in the classroom, originally developed for use with children with hearing impairment, is becoming more commonplace in special school age populations with normal hearing sensitivity. The most recent clinical practice guidelines from the American Academy of Audiology (2008) in the area of remote microphone hearing assistance technologies for children specifies "children and youth with normal hearing sensitivity who have special listening requirements" (p. 5) as one of three listener groups who are potential candidates for some sort of remote microphone hearing technology. The guidelines further list these subgroups: English language learners and children with auditory processing deficits, learning disabilities, language deficits, and/or attention deficits. HAT arrangements recommended for children with normal hearing are either personal FM systems with FM-only ear level, body, or desktop receivers or sound distribution systems that amplify the speech signal and deliver it throughout the classroom through loudspeakers installed on the walls or ceilings (AAA, 2008; Kreisman & Crandell, 2002). The recommendation of HAT for children in this population should be considered on an individual basis, using appropriate measures to determine the need for HAT and to validate the use of the particular technology selected (ASHA, 2002b, 2005, Rosenberg, 2002). Special emphasis should also be placed on assessing the classroom listening environment to ensure the best possible academic outcome (Johnson, 2010). Environmental modifications complement the use of HAT, help enhance acoustic access to speech, and facilitate learning through the auditory mode. If HAT is desired or recommended, the educational audiologist would be the most qualified professional to evaluate the need for HAT, to dispense it and monitor use, and to measure outcomes with HAT in the classroom. The question arises if functional measures typically used to justify and validate the use of HAT for children with hearing loss will be applicable to groups of children with normal hearing who show special listening needs.

The Functional Listening Evaluation (FLE; Johnson & VonAlmen, 1997) was designed to assess speech recognition in school age children with hearing impairment under conditions simulating a typical classroom. By testing speech recognition across various conditions, the clinician examines how noise, distance and visual input may affect a child's understanding of speech in the classroom setting. The FLE is commonly used by educational audiologists to determine situational effects on speech understanding, to provide evidence for the need of HAT, to validate the use of HAT, or any combination thereof (Anderson & Smaldino, 2012; Johnson, 2010; Lewis, 2010). In designing an individual education program (IEP) for a child with hearing loss, the FLE has been suggested to fulfill IDEA's requirement of an "evaluation of the needs of a child with a disability, including a functional evaluation of the child in the child's customary environment" (Assistive Technology 34FR300.6 [Part B]). The FLE has been recommended as particularly useful to assess children with minimal/mild losses and those with auditory processing disorders (Lewis, 2012; Haider, 2009) whose deficits in speech perception in noise tend to be more subtle than those of children with moderate to profound degrees of hearing loss.

The FLE has a number of advantages in assessing classroom listening. Speech recognition performance is measured directly, resulting in quantifiable data. The percent correct scores yielded by the FLE may be subject to less examiner bias than teacher rating scales. Relatively objective, quantifiable measures are valued in justifying intervention strategies, especially when recommending that a school district purchase hearing assistive technology for a particular classroom or child. The FLE protocol is flexible; a number of variables can be adapted depending on the purpose of assessment and the situation of the particular child. Ideally, the FLE is conducted in the child's own classroom (or a comparable one) when it is unoccupied. The fact that the assessment takes place in a classroom setting and simulates typical conditions provides some ecological validity when compared to speech recognition testing in the audiological booth. Additionally, the decision matrix allows the examiner to evaluate the effects of noise, distance, and visual input on speech understanding, making it easier to align recommendations to assessment data. The FLE was developed for use with children who have hearing loss; however, it might also be a useful clinical tool in evaluating children with language and reading impairments, but normal hearing. The FLE could potentially assist in documenting situational listening difficulties in this population and in providing evidence for need of auditory-based interventions, including HAT.

Though it is recommended often as a functional assessment tool (AAA, 2008; Anderson & Smaldino, 2012; Elkayam, 2008; Johnson, 2010), the clinical effectiveness of the FLE has not been evaluated thoroughly in the literature. There is no research that documents the FLE performance of children with normal hearing who are typically developing. Data are also limited regarding its use with children who have special listening needs, but normal hearing. To date, no study has examined the value of using the FLE in children with language and reading impairments to evaluate the potential need for classroom accommodations and/or assistive technology.

The purpose of the current study was to answer the following questions:

1) Does the FLE show reduced sentence recognition in the presence of background noise, distance, and/or lack of visual cues in children with reading difficulties but normal hearing?
2) Does the FLE demonstrate poorer speech recognition performance in children who are judged by parents to have listening problems when compared to children who are judged by parents to have no significant listening difficulties?
3) Are children's ratings of listening difficulty associated with their sentence recognition scores?

Methods

Participants

The participants were selected from attendees of a university-sponsored language and literacy program, an intensive month-long day camp held in the summer; the activities are focused on improving language and literacy skills. The total number of participants was 41: 28 males and 13 females. Children were between the ages of 7 and 10;11 (years; months) inclusive. All children passed a bilateral hearing screening at 1000, 2000, and 4000 Hz at 20 dB HL. All children were diagnosed with oral and written language disorders related to literacy by certified, licensed speech-language pathologists associated with the university clinic. Informed parental consent was obtained for each participant after approval from the university Institutional Review Board. Each participant was paid twenty dollars.

Due to the expectation that the participants would vary widely in perceptual abilities, the group of children with reading difficulties was further subdivided using the Fisher's Auditory Problem Checklist (Fisher, 1985). This checklist is used commonly in schools to assess auditory areas of concern for children with hearing loss and/or to determine whether students with normal hearing sensitivity require further assessment of auditory processing (Emanuel, 2002). The intent in using the Fisher's was not to screen for (nor to diagnose) auditory processing disorder, but to quantify parental observations of listening ability and to identify a subgroup of children with reported listening difficulties.

The Fisher's Checklist is designed as a teacher or parent questionnaire. It has 25 behavioral target items, and the parent checks each behavior that is observed in the child. The score is derived from the percentage of unchecked items; a higher percentage indicates better function and less need for evaluation. It takes little time to complete and has a clear recommendation of a cut-off score to determine the need for further evaluation. The suggested criterion for referring a child for further assessment is a score of 72 percent. In the current study, parents completed the Fisher's Checklist and returned it to the principal investigators with the consent form. Children with scores equal to or less than 72% were assigned to Group 1 (Listening Difficulty, n=22), and children with scores greater than 72% were assigned to Group 2 (No Listening Difficulty, n=19). Group 1 had a mean age of 8;10, and the mean age for Group 2 was 9;1, with no significant difference in mean age between the groups. The examiners who administered the FLE were blind to the Fisher's score and group classification of each child.

Procedure

The FLE was administered by two undergraduate student researchers in an unoccupied classroom in the same building in which the day camp was taking place. Training and supervision of the student researchers were provided by a licensed, certified audiologist. The FLE protocol (2002 revision of Johnson & Von Almen, 1997) was used. Each child was asked to repeat short sentences (Standard American English version of the BKB sentences; Bench, Koval & Bamford, 1979, Kenworthy, Klee, & Tharpe, 1990) presented in eight different listening conditions (see set-up in Figure 1; for list of conditions and sequence see Table 1). The BKB/SAE sentences have simple structure and a vocabulary appropriate for use with children with normal hearing as young as five years of age (Johnson, Benson, & Seaton, 1997). Each sentence was presented only once. There are eight BKB sentence lists, with 50 target words per list; children are scored by the percentage of key words repeated correctly. The order of the sentence lists was counterbalanced, but the sequence of the listening conditions was kept the same as was recommended in the FLE protocol.

The student researchers worked in pairs; one examiner presented the sentences using monitored live voice while the other sat near the child and recorded the child's responses. All children in the study were intelligible; some children showed articulation errors, most commonly distortion or substitution of another phoneme for /r/. Any articulation errors were treated so as not to influence scoring; that is, words with consonant substitutions or distortions were not counted incorrect if the child consistently showed the substitution/distortion throughout the session. For example, if a child who consistently substituted /w/ for /r/ said /wæn/ for 'ran', the word was counted correct. The examiners alternated roles with every other child. Each participant wore a wireless lapel microphone during the testing session, which transmitted his/her voice to a digital recorder; responses were recorded, digitized and saved as a sound file to refer to for any questions about scoring and to establish inter-observer reliability. The level of sentence presentation (average of 75 dBA SPL) was monitored using a sound level meter (Larson-Davis DSP80) placed one foot away from the speaker's mouth. The sound level

Table 1. Sequence of Listening Conditions in the FLE

Order	Condition	Abbreviation
1	Auditory-Visual Close Quiet	AVCQ
2	Auditory Close Quiet	ACQ
3	Auditory-Visual Close Noise	AVCN
4	Auditory Close Noise	ACN
5	Auditory-Visual Distant Noise	AVDN
6	Auditory Distant Noise	ADN
7	Auditory Distant Quiet	ADQ
8	Auditory-Visual Distant Quiet	AVDQ

meter was calibrated before each test session. During the 'Noise' conditions, a recording of multi-talker babble was used; the volume was adjusted so that the noise level averaged 60 dBA SPL at the child's ear. During the 'Auditory only' conditions, a screen made of acoustically transparent material prevented view of the speaker's face. The child was seated in a desk, and the examiner stood three feet from the child in the 'Close' conditions and moved to 15 feet away in the 'Distant' conditions. Immediately following the presentation of each sentence list, the participants were asked to rate the difficulty of the listening task on a 5 point scale (1 = very easy, 5 = very difficult), and each child's rating was recorded on the score sheet.

Inter-observer reliability was measured for the sentence recognition scores (key word scoring). A graduate student in speech-language pathology listened to the recorded sessions of 20% of the participants selected randomly by patient number and determined scores for each condition. There were two children from this subsample who were noted to have consistent articulation errors (mostly /r/ errors); this was similar proportionally to the children with sound distortions/substitutions in the overall sample. These scores were compared to those of the original examiners. The correlation between observer scores was .92 collapsed across conditions, ranging from .87 to .99. The recordings were also used to re-evaluate the FLE for all participants (n=39, one child in each group had missing recordings) using a verbatim scoring strategy. In verbatim scoring, the scores were based on the percent of sentences rather than key words correctly repeated, and the sentences had to be repeated exactly as the examiner presented them to be judged correct. Articulation errors were taken into consideration as described above.

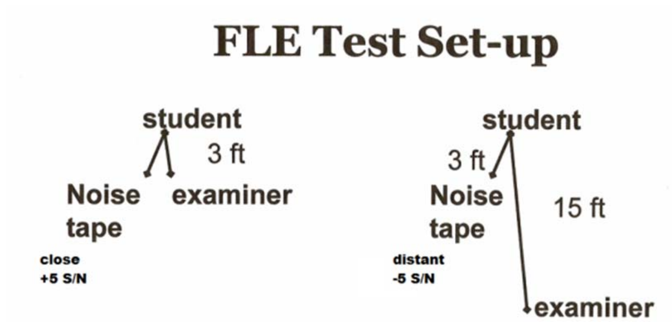

Figure 1. Physical set-up of the FLE test environment. Adapted from the 2002 revision of "The Functional Listening Evaluation" by C. D. Johnson and P. VonAlmen. Retrieved from http://www.handsandvoices.org/articles/education/ed/func_listening_eval.html. Copyright 2005 by Hands and Voices. Reprinted with permission.

Results

Fisher's Auditory Problems Checklist

The mean score for Group 1 (Listening Difficulty, LD) was 53% (SD 16%), and the mean score for Group 2 (No Listening Difficulty, NLD) was 82% (SD 5.6%). The mean score for Group 1 was just above the 50.4% score reported to represent two standard deviations below the normative mean for all age groups. The range of scores for Group 1 was 8% to 72%. The mean score for Group 2 was slightly below the normative means for 7- to 11- year olds (ranging from 85.6 to 87.4%), but scores ranged from 76% to 92%, all within one standard deviation of the normative group mean for all ages (68.6%). Scores on the Fisher's Auditory Problem Checklist were not correlated with age.

Table 2. Key Word Scoring: Mean Percent Correct by Parental Rating Group

Group	AVCQ	ACQ	AVCN	ACN	AVDN	ADN	ADQ	AVDQ*
LD	96.6	96.5	96.9	97.2	96.2	96.3	96.3	95.5
No LD	98.5	98.1	97.6	98.5	97.5	96.3	97.9	98.4

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty. * $p < .05$, one-tailed

Table 3. Verbatim Scoring: Mean Percent Correct by Parental Rating Group

Group	AVCQ	ACQ	AVCN	ACN*	AVDN	ADN	ADQ*	AVDQ*
LD	86.9	87.8	87.5	83.9	85.7	82.1	84.2	82.4
No LD	92.4	93.1	90.6	92.7	88.9	87.9	90.6	93.1

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty; * $p < .05$, one-tailed

Functional Listening Evaluation

When using key-word scoring, speech recognition scores for the FLE were high overall. The mean percent correct scores for the entire sample are shown in Table 2. No child scored below 80% under any condition. There were 50 target words in each sentence list; no child missed more than 10 words in any condition. Mean percent scores did not vary across the eight listening conditions. There was no significant correlation between age and percent correct under any condition. Children with listening difficulties demonstrated slightly lower mean recognition scores for every condition; however, mean scores for Group 1 were still high, ranging from 95.5 to 97.2%. A series of *t*-tests for independent samples demonstrated a significant difference between groups only for the last condition: Auditory-Visual/Distant/Quiet (AVDQ). Group 1 showed greater variability in speech recognition scores in all conditions; only children in Group 1 had scores that were lower than 2 standard deviations below the mean for the entire sample.

When using the more stringent verbatim scoring, the mean recognition scores decreased for both groups across all conditions (see Table 3). Group 1 scores decreased by a greater extent than Group 2 scores for all conditions. The AVDQ condition (Auditory-Visual/Distant/Quiet) showed the greatest difference between the groups for mean percent correct. The *t*-tests for independent samples showed that the between-group difference in mean number of sentences missed was significant ($p < .05$) for the AVDQ, ADQ (Auditory-only/Distant/Quiet), and ACN (Auditory-only/Close/Noise) conditions, with Group 1 missing more sentences. The variability within both groups increased using verbatim scoring, though the maximum score for all conditions was 100% for each group. Both groups demonstrated the lowest mean score for the most difficult condition, ADN (Auditory-Only/Distant/ Noise). There was no correlation between age and percent correct under any condition. As expected, the key-word scores for each condition were correlated significantly with the verbatim scores for the same condition (correlations ranged from .66 to .89).

The FLE scoring includes an interpretation matrix that averages performance across the different conditions to allow the examiner to determine effects of the three variables (noise level, distance, or presence of visual cues) on speech recognition. The mean scores (based on verbatim scoring) for each group averaged across the relevant conditions are shown in Table 4. Several *t*-tests for dependent samples were performed; a statistically significant difference was present in the mean number of sentences missed between the quiet conditions and the noise conditions for Group 2 (higher number of sentences missed in noise), but not for Group 1. Means did not differ for either group between Auditory-Visual conditions in comparison to Auditory-only conditions. A significantly higher number of sentences was missed by both groups in distant conditions relative to close conditions.

Perception of Listening Difficulty

The mean rating of listening difficulty ranged from 1.2 (AVDQ) to 2.26 (ADN) for the entire sample. Individual ratings of 4 and 5 (greatest difficulty) occurred primarily for conditions with noise. Overall, children's rating of listening difficulty was correlated to percent correct only in the close, quiet conditions ($r = -0.45, -0.39$). The same trend was evident when using verbatim scoring. The two groups did not differ in their mean ratings across the conditions. The conditions in order of perceived difficulty (easiest to most difficult) are shown in Table 5. The conditions were ranked according to the mean listening difficulty ratings for the whole sample. The quiet conditions are ranked 1-4 (easier) and the conditions with noise are ranked 5-8 (more difficult).

Table 4. Verbatim Scoring: Interpretation Matrix for Mean Percent Score by Parental Rating Group

Group	Quiet %	Noise %	Close %	Distant %	Auditory-Visual %	Auditory Only %
LD	85.5	84.8	86.5	83.6 *	85.6	84.5
No LD	92.3	90.0 *	92.2	90.1 *	91.2	91.1

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty. Significant differences shown between conditions (Quiet vs. Noise, Close vs. Distant).
* p < .05, one-tailed

Table 5. Mean difficulty for FLE conditions as ranked by participants

Condition	Mean Rating
AVDQ	1.2
AVCQ	1.6
ADQ	1.7
ACQ	1.8
AVCN	2.0
AVDN	2.1
ACN	2.2
ADN	2.3

Note. Conditions were rated by participants across the entire sample. A higher number indicates a listening condition rated as more difficult.

Discussion

Functional Listening Evaluation

Key word scoring. The present study used the FLE to determine whether children with reading difficulties showed reduced speech recognition in the presence of noise, increased distance from the speaker, or lack of visual cues. The BKB/SAE sentences were selected to prevent vocabulary level or complex sentence structure from contributing to the participants' speech recognition performance. Using conventional key word scoring of the BKB/SAE sentences, the scores were notably high for the entire sample of children across the eight listening conditions.

The lowest score for an individual child under any condition was 80%. Mean speech recognition scores were above 95% for all conditions. There was limited variability, but age did not contribute to the children's performance under any condition. The reduced performance range and high scores suggest that with key word scoring of the BKB sentences, the FLE as conducted in this study was a relatively easy task for the 7- to 10-year-old children with reading difficulties, but normal hearing. Use of sentence material to measure speech recognition provided semantic and syntactic context to assist with key word identification. The BKB/SAE sentences were used by Lewis and coworkers (Lewis, Hoover, Choi, & Stelmachowicz, 2010) as one measure of speech perception in noise. Scoring sentences correct only if all three key words were correct, they still encountered ceiling effects at a +5 signal-to-noise ratio for 5- to 7-year-old children who were typically developing. Even at 0 dB signal-to-noise ratio, mean scores for the 5-year-olds were above 80%. Clearly, more difficult speech material should be used for any elementary school age population with normal hearing to discover potential perceptual deficits in noise. Bradlow and coworkers (2003) suggested that children with reading impairments may depend more on context than their typically-developing peers, so the use of children's nonsense phrases might provide a more challenging task for this group, with an appropriate vocabulary level but without syntactic or semantic cues to the identity of key words.

An important difference between the FLE protocol and some procedures reported in the literature is that the FLE task is set up so that there is spatial separation between the source of the signal and the noise source (see Figure 1). In numerous studies showing marked speech-perception-in-noise deficits for children in special populations, recorded speech stimuli are mixed with noise and delivered via earphones or a loudspeaker in front of the child (e.g., Bradlow et al., 2003; Crandell & Smaldino, 1996). Thus, the signal is embedded in noise and both are coming from the same direction. Speech perception in this condition is a more difficult task than understanding speech when the interfering noise is spatially separated from the signal source (Cameron, Dillon, & Newall, 2006; Johnstone & Litovsky, 2006). This may explain in part why children in this study showed relatively high speech recognition scores even in disadvantageous conditions. The FLE's orientation of the noise source and signal source is likely more representative of conditions in classrooms where most noise sources surround the students and typically do not come from behind the teacher.

The Fisher's Auditory Problem Checklist was used to identify a subgroup of children with listening difficulties based on conclusions drawn from parental observation. We were interested in whether the FLE would reveal differences between the LD and no LD groups. Interestingly, the parental responses divided the total sample of children with language and reading impairments into two roughly equal groups (22 in Group 1, LD, and 19 in Group 2, No LD) using the suggested 72% cut-off score. The mean age of Group 1 was slightly lower than that of Group 2; this was not a significant difference, nor were there correlations between age and any of the measures. There were proportionally more males in Group 1 (77% versus 58% in Group 2). The FLE as conducted in this study was largely insensitive to differences between children with and without listening difficulties when using the conventional key word scoring of the BKB sentence materials. Though the LD group showed significantly lower mean scores than the no LD group for the last condition in the sequence, Auditory Visual/ Distant/ Quiet (AVDQ), the effect size was small; in addition, mean scores were above 95% for both groups.

Verbatim scoring. Rescoring the FLE using a stricter verbatim scoring strategy generally reduced scores and yielded greater variability. Using the more rigorous verbatim scoring seemed to affect Group 1 (LD) to a greater extent than Group 2 (no LD), resulting in more evident differences between the two groups. The variability within Group 1 was always greater than for Group 2, regardless of condition. This trend was also apparent for key word scoring, but to a lesser extent. The poorest scores for the entire sample in each condition were always from children in the listening difficulty (LD) group; maximum scores of 100% for each condition were obtained for participants in both groups. Though mean sentence recognition scores were lower for the LD group in all conditions, only three conditions showed statistically significant between-group differences: Auditory/Close/Noise (ACN), Auditory/Distant/Quiet (ADQ), and Auditory-Visual/ Distant/Quiet (AVDQ). The ACN condition is the most acoustically difficult of the close conditions (noise added, no visual cues). The ADQ and AVDQ conditions, while less acoustically rigorous due to lack of noise, may have been more difficult for the LD group because they were the last two tested in the FLE sequence. Both the LD and no LD groups showed their poorest performance overall in the ADN (Auditory/Distant/Noise) condition, with means of 82.1% and 87.9% for Group 1 (LD) and Group 2 (no LD), respectively. The mean scores for Group 2 improved for the two noiseless conditions following ADN (ADQ and AVDQ), as would be expected for comparable conditions in quiet, while mean scores for Group 1 (LD) did not change appreciably for the last two quiet conditions when compared to ADN. The entire FLE protocol took between 25 and 40 minutes for each child; there may have been effects of reduced attention or fatigue in Group 1 that decreased performance somewhat for the last two quiet conditions in the sequence. In other words, the children with listening difficulties may have been expending greater effort on the FLE than those without; they may not have been able to sustain the same level of attention over time, which could have reduced their performance in the later conditions, confounding the effect of acoustic difficulty. Further research on the effect of condition sequence would be helpful to determine whether potential order effects exist.

The FLE interpretation matrix compares scores averaged across conditions to evaluate the variables of noise, distance, and visual input. When evaluating group means averaged across conditions, there was a significant effect of distance for both groups of children (LD and no LD); not surprisingly, scores were poorer in the distant conditions compared to the close conditions. Given that the distant conditions are intended to establish a less desirable signal-to-noise ratio because of the decreased signal level at 15 feet, it is somewhat surprising that only Group 2 (No LD) showed a significant noise effect when compared to the children's performance under quiet conditions. As noted above, Group 1 means were significantly lower than Group 2 means for the last two conditions in the FLE sequence, both in quiet. This may have depressed the LD group's averaged scores in quiet conditions enough to eliminate any significant difference between the conditions with and without noise, especially since the effect size is so small (approximately 2-3 point differences in group mean scores between conditions). Thus, the lack of a significant noise effect in the LD group may be due to the effects of fatigue or reduced attention on the last two quiet conditions. When averaging across conditions, the absence of visual cues did not affect speech recognition for either group.

Our study, consistent with past work, showed the poorest sentence recognition performance for children in both groups occurred in the Auditory/Distant/Noise condition; this condition provided the lowest signal-to-noise ratio (distance of 15 feet decreased the signal level, multi-talker noise present). Thus, children with language and reading impairments, with or without reported listening difficulties, were least accurate at recognizing speech when the signal-to-noise ratio was lowest (approximately -5 dB). The condition that distinguished most between the LD group and the no LD group (that is, where the difference between group means was the largest) was also a distant condition: Auditory Visual/Distant/Quiet. Though designated a 'Quiet' condition, there is always ambient classroom noise, which, combined with the lower signal level at the child's ear in the distant condition, may produce a less than ideal signal-to-noise ratio. On the average, children in the no LD group were able to take advantage of visual cues or the lack of multi-talker noise to achieve better speech recognition in the AVDQ condition than in the more difficult ADN condition, while the children in the LD group were not. Children without reported listening difficulties (Group 2) may have been more attentive to visual and auditory cues available in this condition. They may have been less affected by the lower signal level in the absence of the moderate levels of multi-talker competing noise. An ability to understand speech at a distance increases the likelihood that incidental learning will occur. For example, a child who overhears the teacher answering another child's question may not have to ask for clarification herself. As suggested before, since AVDQ is the last condition in the FLE sequence, children in the LD group may have been less attentive due to fatigue at maintaining the effort needed to listen, resulting in poorer performance. In this study, the FLE was administered after the child had attended the day camp where they participated in three hours of language and reading intervention. If children in the LD group were experiencing fatigue towards the end of the FLE, their ratings of listening difficulty might be expected to rise for the last condition, but this was not the case, nor did their mean rating differ from the no LD group in any condition. This may suggest that children in the LD group were not aware of errors they were making. Further research determining how acoustic environment and task demands interact to challenge children with special listening needs may help clarify these results.

Regardless of the reason, the FLE indicated that greater distance and decreased signal-to-noise ratio increased the difficulty of the speech recognition task in this clinical population, particularly for children with reported listening difficulties. A teacher with numerous children with special listening needs in the same classroom may find it difficult to give preferential seating to all to reduce distance effects. The teacher location within the room that may be advantageous for listening for some children may be disadvantageous for others. Even teachers who effectively manage the room's noise level on a consistent basis will not be able to provide an ideal signal-to-noise ratio for all students at all times, nor can they control variables, such as transient or fluctuating hearing loss related to middle-ear disorders that may be present intermittently in some children who already have listening difficulties. Remote microphone HAT is designed especially to alleviate these types of classroom challenges. Sound distribution systems increase the signal-to-noise ratio for all children in the classroom by amplifying the teacher's voice level and work particularly well in classrooms that are not overly reverberant. Personal FM systems provide the highest signal-to-noise ratio possible for individual children who require especially favorable conditions for optimal speech perception. In addition to the speech recognition benefits, the use of classroom HAT may provide other advantages: maintaining students' attention to the teacher's voice, decreasing off-task time, allowing teachers to talk and convey a calm attitude (without having to raise their voices to be heard), increasing opportunities for incidental learning, and decreasing the amount of effort students use to listen, freeing up cognitive and energy resources for higher-level thinking (Heeney, 2007).

Perception of Listening Difficulty. The groups had similar mean ratings of self-perceived listening difficulty across the FLE conditions. The presence of noise seemed to dominate perceived listening difficulty (see Table 5), with the four quiet conditions ranked as easier than the four noise conditions. Children's perception of listening difficulty did not correlate with percent correct scores regardless of scoring strategy except weakly in the close, quiet conditions. This finding is consistent with results from Klatte and colleagues (2010), who found that first and third graders' 'disturbance ratings' of noisy and reverberant conditions were very low (signifying no or little disturbance to listening) and did not correlate with their speech recognition or listening comprehension performance, which was severely affected by the most difficult conditions. On the other hand, considering the relatively high percentage scores for key word recognition overall, low mean ratings (indicating easy conditions) may have accurately represented the difficulty of the listening task overall for this sample of children. Exploring how well children are able to judge the effect of difficult classroom listening conditions on their speech recognition is important because children who do not perceive that they are having difficulty will not know to ask for help or clarification. They may not realize that they misunderstood what the teacher or other students said until they are called upon to respond or use the information in some other way. Further study of whether listening difficulty ratings are associated with acoustic conditions is warranted in this population in situations with a greater range of difficulty.

Study Limitations

Results from the FLE can be used to support the recommendation of HAT use in the classroom for children with listening difficulties. With this in mind, FLE data from a control group of age-matched, typically developing children with normal hearing would have been useful. Evidence that children with language and reading impairments (or other special listening needs) perform significantly poorer in adverse listening conditions than their typically developing classmates is needed to justify the provision of HAT by schools. Data from a control group also might clarify for this age group and speech material what scores would represent a significant reduction in speech recognition in various conditions in comparison to typically developing peers. The FLE is meant to be adapted to the specific classroom environment of the individual child being evaluated, and interpretation of the FLE results for a particular child places emphasis on the effect of the conditions (i.e., noise, distance, absence of visual cues) on the child's speech recognition rather than a comparison of the child's performance to normative values. Even so, FLE data for typically-developing children with normal hearing would help clinicians evaluate the magnitude of speech recognition deficits in clinical populations as well as the amount of benefit gained by the use of HAT.

In recognition of the heterogeneity of this study's participants despite the common diagnosis, the Fisher's Auditory Problems Checklist was used to designate a subgroup with listening difficulties within the clinical population of interest. The Fisher's Checklist was selected in part because it takes little time to complete and has a clear recommendation of a cut-off score to determine the need for further evaluation. Defining the subgroup with listening difficulties based solely on parental responses to the Fisher's Auditory Problems Checklist may limit interpretation of this investigation's results. Parent perceptions are subjective, and the Fisher's Checklist and other similar questionnaires have been demonstrated to be ineffective at predicting a diagnosis of APD. Questionnaire results have also been shown to be poorly correlated with performance on individual tests of auditory processing (Dawes, Bishop, Sirimanna, & Bamiou, 2008; Wilson et al., 2011). Additional measures, such as standardized, recorded speech-in-noise tests performed in a sound-treated booth, could have been used to support the parent ratings in identifying a subgroup of children who consistently show difficulty with speech recognition in unfavorable listening situations. In the current study, the Fisher's Auditory Problems Checklist was considered to be a functional measure used to describe ongoing problems related to listening rather than a screening tool or diagnostic test for a particular disorder.

Studies comparing speech perception in noise for children in special populations to that of typically developing children tend to be conducted in a sound-treated environment. Differences between experimental and control groups are typically greater in the most adverse listening conditions—for example, the lowest signal-to-noise ratios. Bradlow and coworkers (2003) compared speech perception for children with and without learning disabilities using the BKB sentences at two different signal-to-noise ratios. Children in the current study (entire sample) performed better in the FLE's most difficult listening condition (ADN, Auditory/Distant/Noise) than either group in the Bradlow et al. study did at the most comparable condition: female talker using clear speech with speech level at 65 dB SPL and noise adjusted to a -4 dB signal-to-noise ratio. In the ADN condition of the FLE, the noise level is kept constant at 60 dBA at the child's ear, and the signal level is expected to drop with distance to provide a signal-to-noise ratio of approximately -5 dB. Though each examiner monitored her level of presentation using a sound level meter mounted a foot away, the dB SPL of the examiner's voice was not measured at the ear of the listener. It is possible that a -5 dB signal-to-noise ratio was not achieved; that is, that the children were experiencing a somewhat higher signal-to-noise ratio, making the distant task easier than expected. The most recent version of the FLE (revised 2011 by Johnson, available at http://successforkidswithhearingloss.com/wp-content/uploads/2011/08/FLE-2011_autocalculate_saveable2.pdf) recommends confirming that the examiner's voice is at 65 dBA SPL at the listener's ear with the examiner standing in the close condition at a distance of three feet rather than extrapolating from a measurement made closer to the examiner. In future research on the FLE, both the signal and the noise level should be verified at the child's ear.

Conclusions/Clinical Implications

Children with language and reading impairments are among numerous groups of individuals with normal hearing who may benefit from the use of hearing assistive technology in the classroom (AAA, 2008; Crandell & Smaldino, 2000). The FLE is often used to provide a rationale for HAT use in the classroom for children with hearing loss, and might also be useful for the same purpose when evaluating children like the participants in the current investigation. The FLE, as conducted in this study, was largely insensitive to differences between children with and without listening difficulties (based on parental responses to the Fisher's Auditory Problems Checklist) when using the conventional key word scoring of the BKB sentence materials. The fact that rescoring responses with a more rigorous criterion resulted in greater variability and demonstrated larger differences between the two subgroups and between conditions suggests that modifying some of the parameters of the FLE to create more demanding listening tasks would potentially increase its value for use with children who have normal hearing, but special listening needs. In particular, the use of speech material with no syntactic context (e.g., Children's Nonsense Phrases [Johnson, Benson, & Seaton, 1997]) and lowering the signal level would increase the difficulty of the speech recognition task across the conditions. These changes also might increase the sensitivity of the FLE to potential speech recognition problems of individual children with language and reading impairments. Testing solely the auditory-only conditions (i.e., omitting the auditory-visual conditions) is an option to reduce the test time unless examining the effect of visual cues is relevant for a particular child. Further study is needed to determine what combination of modifications of the FLE would result in conditions that adequately tax children with normal hearing without using unrealistically low signal-to-noise ratios that do not represent typical classroom environments. Investigating the effect of using speech materials varying in length, complexity and amount of context may also be productive when assessing children with language and reading impairments.

With an increasing emphasis on improving classroom acoustics for children with normal hearing who are at risk academically, educational audiologists and speech-language pathologists will be challenged to identify which children will benefit the most from classroom interventions that increase access to speech. The FLE is a standardized but flexible clinical protocol that can indicate what classroom conditions might have a negative effect so reception of information in the classroom can be facilitated as much as possible. The FLE matrix form isolates the effects of distance, noise, and absence of visual cues; it can be helpful to justify the recommendation of particular accommodations (e.g, preferential seating, preservation of visual cues, noise reduction, HAT use to counteract noise and distance effects). Future research should focus on what modifications of the FLE would provide the most useful information to support professional recommendations and also examine the effectiveness of the FLE in measuring outcomes with hearing assistive technology in this population.

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