Research Article

Can Children Substitute for Adult Listeners in Judging the Intelligibility of the Speech of Children Who Are Deaf or Hard of Hearing?

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Purpose: Assessments of the intelligibility of speech produced by children who are deaf or hard of hearing (D/HH) provide unique insights into functional speaking ability, readiness for mainstream classroom placements, and intervention effectiveness. The development of sentence lists for a wide age range of children and the advent of handheld digital recording devices have overcome two barriers to routine use of this tool. Yet, difficulties in recruiting adequate numbers of adults to judge speech samples continue to make routine assessment impractical. In response to this barrier, it has been proposed that children who are 9 years or older might be adequate substitutes for adult listener-judges (Ertmer, 2011).

Method: To examine this possibility, 22 children from the 3rd, 4th, and 5th grades identified words from speech samples previously judged by adults.

Results: Children in the 3rd and 4th grades identified fewer words than adults, whereas scores for 5th graders were not significantly different from those of the adults. All grade levels showed increasing scores across low, mid, and high levels of intelligibility.

Conclusions: Children who are functioning at a 5th grade level or higher can act as listener-judges in speech intelligibility assessments. Suggestions for implementing assessments and scoring child-listeners' written responses are discussed.

For speech-language pathologists (SLPs), assessments of speech intelligibility seek to measure the clarity of the speech produced by children or adults who are deaf or hard of hearing (D/HH) or who have other communicative disabilities. Nicolosi, Harryman, and Kresheck (1996) defined *speech intelligibility* as “that aspect of speech-language output that allows a listener to understand what a speaker is saying” (p. 255). Thus, the ultimate goal of speech training for children who are D/HH is the achievement of readily intelligible, connected speech.

The widespread adoption of newborn hearing screening, advances in hearing aid (HA) and cochlear implant (CI) technologies, and the increased availability of early intervention programs have resulted in improved spoken

language abilities and mainstream educational placements for many children who are D/HH (see, e.g., Chin, Tsai, & Gao, 2003; Ertmer, 2007; Flipsen & Colvard, 2006; Peng, Spencer, & Tomblin, 2004). Assessments of speech intelligibility provide unique information about the functional speech status of these children. The main purposes of this report are to discuss the benefits of routinely assessing speech intelligibility, to review logistical barriers to completing such an assessment, and to determine whether school-age children can substitute for adults as listener-judges in this process. If children are found to be sensitive to improvements in connected speech intelligibility, then recruiting listener-judges will become much more practical for SLPs in typical and special educational settings.

Advances in Speech Intelligibility Assessment

The development of testing materials and advances in audio-recording technology have made assessments of speech intelligibility much more practical and time efficient than in the past. Lists of sentences are now available to assess a wide age range of children. For example, the Beginner's

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Intelligibility Test (BIT; Osberger, Robbins, Todd, & Riley, 1994; see Appendix A) consists of four lists of 10 short sentences incorporating simple vocabulary. The BIT sentences are appropriate for toddlers through the early elementary grades. To administer the BIT, clinicians model each sentence while using toys and small objects to demonstrate the meaning of a sentence (e.g., “The boy walked to the chair.”). The children’s imitations of the sentences are audio-recorded and saved as digital files for later analysis.

Another set of materials, the Monsen–Indiana University (M-IU; Osberger, Maso, & Sam, 1993; see Appendix B) sentences, consists of three lists of 10 sentences that were developed for relatively older children who are capable of imitating sentences following exposure to spoken and written prompts. The M-IU sentences are slightly longer and contain more multisyllabic words and consonant clusters than do the BIT sentences. Imitative speech samples are elicited by having the clinician say each M-IU sentence while the child looks at its written form on an index card. The printed sentence is then removed from sight, and the child repeats the target sentence aloud while it is recorded. Again, children’s imitations of the sentences are audio-recorded and saved as digital files for later analysis. For other lists that can be useful in clinical settings, see Osberger (1992).

With a digital handheld recorder-player or a cell phone with an audio-recording app, the process of eliciting and recording sentences takes less than 5 min in most cases (see Figure 1). The same recorder-player is then used to present the individual sentences (saved as separate sound files) for judges who listen while wearing headphones. The judges then write down the words that they understand in each sentence. Sentences are usually presented twice as several listeners write down the words they understand. All listener-judges can listen to a sample at the same time using an inexpensive multichannel headphone amplifier (also shown in Figure 1).

Figure 1. A Sony digital hand held recorder-player and an Artcessories Headamp4 splitter used to present samples to listener-judges wearing headphones.

The next step in the process is to calculate a speech intelligibility score for each judge. This is accomplished by dividing the number of words that the listener correctly identified by the total number of words that the child said when producing the stimulus sentences. For example, if Listener-Judge A identified 10 of the 40 words that a child said when producing 10 BIT sentences, the intelligibility score would be 25% for this listener-judge. An overall score is determined by averaging scores across several listener-judges. For example, if Listener-Judges A, B, and C had scores of 25%, 30%, and 35%, the child’s overall intelligibility score would be 30%. The time needed to elicit and record a speech sample and play it for listener-judges is comparable to or less than the amount of time needed to administer, transcribe, and score a test of articulation, or to complete a phonological process assessment. For more information on intelligibility assessments for children who are D/HH, see Osberger (1992) and Ertmer (2011).

Obtaining intelligibility scores at regular intervals (e.g., every 6 or 12 months) enables SLPs to track children’s progress toward readily intelligible connected speech. This information is crucial for documenting the achievement of speech-related individualized education program (IEP) goals and making placement, planning, and dismissal decisions.

Uses for Speech Intelligibility Scores

Several important uses for speech intelligibility scores have been identified by Ertmer (2010, 2011) and Monsen (1981). First, it has been shown that speech intelligibility and speech perception ability have a high correlation in children with CIs (Blamey et al., 2001; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000). Increases in intelligibility scores are likely to reflect improved speech perception for HA and CI users. Conversely, limited gains in intelligibility might indicate that children do not adequately recognize the segmental and suprasegmental features of conversational speech via their sensory aids. Adjustments—such as CI remapping or HA adjustment—might be indicated if audiometric tests confirm perceptual difficulties.

Second, assessments of speech intelligibility enable clinicians to estimate children’s functional oral communication ability—that is, how well children can be understood by individuals with normal hearing. Because single-word articulation test scores have shown little relationship to connected speech intelligibility in children who are D/HH (Ertmer, 2010), assessment of sentences (vs. assessment of single words) is needed to examine functional speech intelligibility. If limited progress is observed across multiple assessments, then increased emphasis on generalization of phoneme targets to connected speech would be warranted. Such an approach focuses on the transfer of targets to connected speech in meaningful situations. A description of a constructivist approach to facilitating carryover can be found in Ertmer and Ertmer (1998).

Finally, intelligibility scores can be used to estimate communication competence in mainstream classrooms.

That is, scores—when used in conjunction with evaluations of social and academic abilities—can help clinicians determine whether children are ready for mainstream placements. They also provide objective estimates regarding how well those who are already mainstreamed can be understood by their teachers and classmates.

Barriers to Assessing Speech Intelligibility

Despite these important clinical uses, speech intelligibility assessments have a long history of underuse in typical education and special education schools for children who are D/HH (Ertmer, 2011; Monsen, 1981). In the past, three barriers appeared to be mainly responsible for this neglect: (a) a lack of assessment materials for preschool and elementary school children; (b) time-consuming procedures that required recording and parsing children's utterances from audio-taped or CD-recorded speech samples, saving them as individual digital sound files, and then making playlists for listeners; and (c) difficulty in recruiting adults to serve as listener-judges. The increased availability of sentence lists and handheld digital recorder-players as well as cell phones with audio-recording and file-saving capabilities have helped SLPs overcome the first two barriers. A new alternative is needed to address the third barrier if speech intelligibility assessments are to become a routine part of a speech and language evaluation for school-age children who are D/HH.

Recruiting Listener-Judges

Adults who have normal hearing and little or no exposure to the speech of children who are D/HH have often served as listener-judges in studies of speech intelligibility. Although it is certainly possible to recruit adults in school settings, finding a sufficient number of willing adults and making arrangements for them to listen to samples is time-consuming and often impractical given clinicians' large caseloads.

Recently, it was proposed that children 9 years of age or older might be able to substitute for adults as listener-judges (Ertmer, 2011). The rationale for this idea was that such children have the literacy skills needed to write down the simple words contained in lists such as the BIT and M-IU sentences. Thus, if children are performing at a fourth-grade level or higher in reading and spelling, have good motivation (i.e., are willing to volunteer), and show adequate attention, then they might be able to identify words from these lists as competently as do adults. The main advantages of this approach are that children are readily available in schools, are often willing to volunteer for extracurricular activities, can be conveniently scheduled for listening sessions, and, in most cases, have documentation of passing hearing screenings. Although this proposal has face validity, it has not been investigated directly.

Research Questions

In the current study, we sought to determine whether children who have normal hearing would be acceptable listener-judges of the connected speech intelligibility of

children with hearing loss. Two research questions were examined: (a) Do scores for children differ from those of adults when judging samples of low, mid, and high speech intelligibility? (b) Do children in third, fourth, and fifth grades differ across low-, mid-, and high-intelligibility speech samples?

Method

Participants

A total of 22 students from a small private school were enrolled as listener-judges for SLPs in educational settings. The study was explained in three classrooms, and all children who returned parent consent forms were enrolled as participants. These included 7 third graders (8–9 years old), 9 fourth graders (9–10 years old), and 6 fifth graders (10–11 years old) who were performing at grade level. The students passed a hearing screening (American Speech-Language-Hearing Association, 1997) before participating as listener-judges. For comparison, six adults who had previously identified words in speech samples also provided scores. These adults were part of a larger group of listeners and were assigned children's samples prior to the determination of intelligibility scores and levels. All of the adults were between 18 and 40 years of age and had hearing within normal limits. None of the children or the adults had any previous experience listening to the speech of children who are D/HH.

Audio-Recorded Materials

Digitized audio recordings of three orally communicating children with CIs served as speech stimuli. All of the children had prelingual, severe-to-profound, bilateral hearing losses and were participants in an ongoing study of postimplantation speech development. All participants had received CIs before age 3;0 (years;months; $M = 26$ months at first implantation) and had approximately two years of CI experience when the samples were recorded. One of the children received a second CI at age 3;2. Their audio-recorded samples were selected for this study because they corresponded to low ($M = 38\%$), mid ($M = 53\%$), and high ($M = 80\%$) intelligibility levels on the basis of scores from the adult listener-judges.

Procedures

Speech samples were recorded with a Sony mini-DVD camcorders (Model No. DCR-DVD405; Sony Corporation of America, New York, NY) coupled with Bluetooth wireless microphones to make audio and video recordings. The microphone was placed within 4 in. of the child's mouth. The same adult listeners did not listen to each of these lists because children's samples were analyzed by panels of listeners at different points in time, and representatives of low, middle, and high levels of intelligibility were selected after all samples had been judged. For the adult group, three listeners had evaluated samples from the low and mid levels

of intelligibility. Another three participants had listened to the high-level sample only.

Recordings of three different BIT lists were played for the child listener-judges using a portable CD player (Lennox Sound Models CD-102 or BP-103; Lennox Electronics Corp., Edison, NJ), a multichannel amplifier (Artcessories Headamp-4; Applied Research and Technology, Niagara Falls, NY), and Sony headphones (Models MDR-CD180 or DR S100; Sony Corporation of America, New York, NY). Listening checks for each recording and each set of headphones were performed by the first author and by an assistant before the stimuli were presented to the child listener-judges. The purpose of the check was to ensure that the headphones were working and that the recorded sentences were not distorted. Next, a practice trial was conducted to ensure that the task was understood and that the children had adjusted their headphones to a comfortable listening level. They were also instructed to mark an "X" if they were unsure of a word. This was done to help maintain attention to task whenever speech was difficult to understand. During actual testing, each BIT sentence was played twice, with a pause between presentations and another pause after the second presentation so that the children had ample time to write their responses. Each new stimulus item was introduced when all children had finished their written responses for the previous item. Children were instructed to cover their answers so that others could not see them. For each group of students, the samples were played in order of intelligibility—first low, then mid, then high.

The children's written responses were collected and scored for the percentage of written words that matched the words produced by the CI users (i.e., percentage of words correctly identified). Written word responses were scored as matching the child's utterance when the root of the spoken word was identified. For example, if a talker said "jumps" and the listener's written response was "jump," then the response would be scored as a match. Similar procedures and scoring conventions have been described in studies using adult listener-judges (Chin et al., 2003; Ertmer, 2007). Recognizable words with spelling errors were also accepted as matches. For each child listener-judge, a percent-intelligible score was calculated by dividing the total number of correctly identified words by the total number of words produced in each recorded BIT sample. Percent-intelligible scores were calculated for the low, mid, and high samples for each child listener-judge. Additional information on scoring can be found in Ertmer (2011).

Data Analysis

The children's mean percent-intelligible scores (i.e., percent of words identified across all listener-judges in a grade-level group) were compared with the scores from adult listener-judges previously obtained for the same BIT sentences. The independent variables were group (child vs. adults), intelligibility level of the samples (low, mid, and high), and grade level (third, fourth, fifth, and adults). All of the child listener-judges were evaluated at each level of

intelligibility. The main effects of group/grade and intelligibility level as well as their interaction were evaluated using a linear mixed model (PROC GLIMMIX) with the Kenward-Roger degrees of freedom adjustment. This adjustment is needed because not all adult participants contributed scores at all levels of intelligibility. All *F* tests were evaluated using a .05 significance level. If there were a significant difference, Tukey's pairwise comparison method would be used to describe the difference.

Reliability

Intra- and interreliability measures were undertaken to determine whether children's written responses could be scored consistently. The original percent-intelligible scores for approximately 29% of the children's written responses were compared with (a) the results of a second scoring by the original scorer and (b) those obtained by a different, trained scorer. The samples were randomly chosen and included representatives from talkers with low, mid, and high levels of intelligibility. This analysis showed that both sets of scores in the intra- and interreliability comparisons were highly correlated ($r = .995$ and $r = .961$, respectively). These findings support the notion that children's written responses can be scored in a consistent manner within and across clinicians.

Results

Even though the dependent variable was a percentage score, residual diagnostics showed no major departures of constant variance or normality. For completeness, we also considered the arcsine square root transformation of percentage and found that the test results were the same. Therefore, untransformed percentage scores were used in the analysis. The following results should be considered preliminary for two reasons. First, the total sample of listeners was relatively small: 22 children and six adults. Second, the number of participants at each grade level was also relatively small (third grade, $n = 7$; fourth grade, $n = 9$; fifth grade, $n = 6$).

As far as main effects, there was a significant difference among the levels of intelligibility, $F(2, 49) = 115.62$, $p < .0001$. Pairwise comparisons revealed that all levels were different from one another, with low-level intelligibility having the lowest percentage and high-level intelligibility having the highest percentage. This finding confirmed that the selected samples represented different points along a continuum of intelligibility.

There was also a significant difference among the groups, $F(3, 30) = 3.36$, $p = .0372$. Post hoc Tukey-Kramer pairwise comparisons revealed that adults correctly identified more words than did child listener-judges in third and fourth grade; however, this was not the case for child listener-judges in fifth grade. Significant differences between scores from the children in the third, fourth, and fifth grades were not observed, as can be seen in the close groupings of mean scores in Figure 2.

Figure 2. Comparison of mean percent-intelligible scores between child and adult listeners. Means are presented across low-, mid-, and high-intelligibility samples for each group of listeners.

Finally, there was no significant interaction between grade/group and level of intelligibility, $F(6, 43) = 1.0$, $p = .43$. Figure 2 shows that for each of the four groups (the adults and the three grade levels), there was a consistent pattern of an increase in the percentage of intelligible words between low and mid levels, followed by an even larger rise in percentage of intelligible words between mid and high levels.

Discussion

Acceptability of Children as Listener-Judges

Across all intelligibility levels, adults identified more words per sample than did children (see Figure 2). However, scores for fifth graders did not differ significantly from those of adults. The latter finding indicates that children with normal hearing who are age 10 years and older and who are functioning at a fifth-grade level in literacy areas can be effective substitutes for adults in assessments of speech intelligibility.

The investigation also revealed that relatively younger children might be useful in intelligibility assessments. Recall that the scores of third and fourth graders mirrored the adult pattern of increasing word recognition as the intelligibility of samples improved (see Figure 2). This trend indicates that scores from these children—although likely to underestimate adult levels of word identification—can reveal improvements in speech intelligibility over time. However, because the current study was conducted late in the spring semester of the school year, clinicians who recruit third-grade students earlier in the school year (e.g., fall

semester) might not see similar results due to less well-developed literacy abilities. Therefore, it is recommended that, should fifth graders not be available, only those children in the fourth grade and higher—rather than third graders—be recruited as listener-judges.

Two additional caveats must also be emphasized when discussing the results of this study. First, a relatively small sample of children was examined for each grade level. It would be useful to include more children in future studies. Second, scoring the written responses of children can be more problematic than scoring those of adults. The latter concern will be discussed next.

Notable Differences Between Child and Adult Listener-Judges

As expected, adults and children differed in spelling accuracy and handwriting legibility when identifying words from recorded speech samples. A review of adult responses revealed that words from the BIT were almost always spelled correctly and that legibility was seldom a concern. Alternatively, some of the children in the current study made spelling errors and presented frequent challenges in legibility. Figure 3 shows several instances of these situations for sentences in BIT List 4. For example, Sentence 1 shows a response in which no words are identifiable for the sentence, “The bear sleeps.” It is difficult to isolate single words in this response because the letters are not clearly grouped with spaces between them. This response was scored as having no matches for the spoken sentence. Legibility problems might be reduced if children were asked to type their responses on computer keyboards or read their written

Figure 3. An example of a child listener-judge's written responses to 10 sentences from BIT List 1.

responses for the tester. The latter solution would be possible only when other children are not present. It is fortunate that children in the fifth grade and beyond often have legible handwriting.

As for spelling, some responses were recognizable as words even though spelling errors were made. Examples can be found in Sentences 2 (“momy” for *mommy*), 3 (“rabit” for *rabbit*), 8 (“areplan” for *airplane*), 9 (“panting” for *painting*), and 10 (“coken” for *cooking*). In these cases, the child’s written response closely approximated the target word; thus, credit was given despite spelling errors. In addition, whenever suffixes were not included in a written response (e.g., “jump” for *jumps*), credit was given if the root of the word was identifiable. Whereas individual variation in spelling and legibility are likely to be observed, they do not necessarily interfere with scoring. Recruitment of children who are 10 years and older is likely to reduce the frequency of spelling and legibility concerns relative to younger children.

Clinical Implications and Conclusions

The findings of the current study have addressed a previously noted barrier to speech intelligibility assessment: difficulty in recruiting and scheduling adult listener-judges. It was shown that children with normal hearing who are at least 10 years old and functioning at grade level can substitute for adults in this task. For clinicians in regular education schools who serve mainstreamed children with hearing loss, child listener-judges can now be recruited from classrooms within the same building, thus saving the clinicians time and increasing the likelihood that speech intelligibility assessments will become routine. For clinicians in educational programs devoted to children who are D/HH, child listener-judges with normal hearing—although often not in attendance in the same building—might be recruited from neighboring schools.

In summary, the current findings, the increased availability of sentence lists (see Appendixes A and B), and

improvements in digital recording technology have helped make speech intelligibility assessments much more efficient and practical in school settings. Routine use of these assessments can yield important information for children who are D/HH—information that is not available through traditional phonological evaluations (Ertmer, 2010, 2011; Monsen, 1981).

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Appendix A

Table A1. Beginners Intelligibility Test (BIT; Osberger et al., 1994).

List 1	List 2
<ol style="list-style-type: none"> 1. The baby falls. 2. Mommy walks. 3. The duck swims. 4. The boy sits. 5. Grandma sleeps. 6. That is a little bed. 7. The boy walked to the table. 8. My car is blue. 9. He is brushing his teeth. 10. She is taking a bath. 	<ol style="list-style-type: none"> 1. Daddy runs. 2. The baby cries. 3. The dog eats. 4. The girl drinks. 5. The clown falls. 6. That is a big bed. 7. The boy walked to the chair. 8. My van is green. 9. They are playing the drums. 10. She is talking on the phone.
List 3	List 4
<ol style="list-style-type: none"> 1. Daddy walks. 2. The bunny drinks. 3. The dog sleeps. 4. The girl jumps. 5. Mommy reads. 6. That is a brown chair. 7. The boy is on the table. 8. My airplane is big. 9. He is tying his shoe. 10. She is brushing her hair. 	<ol style="list-style-type: none"> 1. The bear sleeps. 2. Mommy sits. 3. The rabbit hops. 4. The cowboy jumps. 5. Grandma falls. 6. That is a black hat. 7. The boy is under the table. 8. My airplane is small. 9. He is painting the chair. 10. She is cooking dinner.

Note. Toys and small objects used to administer BIT sentences included people (e.g., *baby*, *Mommy*, *boy*, *Grandma*, *Daddy*, *girl*, *clown*, and *cowboy*) and objects (e.g., *duck*, *bed*, *table*, *blue car*, *toothbrush*, *bath tub*, *dog*, *drink*, *green van*, *drum*, *telephone*, *bear*, *rabbit*, *black hat*, *airplane*, *paint*, *pot/pan*, *book*, *brown chair*, and *hairbrush*).

From Osberger, M. J., Robbins, A. M., Todd, S. L., & Riley, A. I. (1994). Speech Intelligibility of Children With Cochlear Implants,” by M. J. Osberger, A. M. Robbins, S. L. Todd, and A. I. Riley, 1994, *The Volta Review, 96*, pp. 169–180. Copyright 1994 by Alexander Graham Bell Association for the Deaf and Hard of Hearing. Reprinted with permission.

Appendix B

Table B1. Monsen–Indiana University (M-IU) Sentences (Osberger et al., 1993).

List 1	List 2	List 3
1. This house is white.	1. Our car is safe.	1. His boat is white.
2. My dog is mean.	2. That lake is deep.	2. My bike is new.
3. Can he make any?	3. Can you tell us?	3. Did we call them?
4. Did you find some?	4. Do you want any?	4. Did you buy it?
5. You got a nice haircut.	5. They saw a long sunset.	5. She ate a good hotdog.
6. We made a nice birdhouse.	6. She saw the poor cowboy.	6. We bought a new baseball.
7. Can he stop them?	7. Can you start it?	7. Did you steal it?
8. Did she bring it?	8. Have they reached it?	8. Did you try it?
9. My grandmother is beautiful.	9. My television is broken.	9. Her sweater is purple.
10. That elephant was dangerous.	10. That newspaper was interesting.	10. The butterfly is sleeping.

Note. From “Speech Intelligibility of Children With Cochlear Implants, Tactile Aids, or Hearing Aids” by M. J. Osberger, M. Maso, and L. Sam, 1993, *Journal of Speech and Hearing Research*, 36, pp. 186–203.