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Assessing speech perception in children with language difficulties: Effects of background noise and phonetic contrast

MAGGIE VANCE1 & NICOLA MARTINDALE2

1The University of Sheffield, Sheffield, UK, and 2NHS Wakefield District, UK

Abstract
Deficits in speech perception are reported for some children with language impairments. This deficit is more marked when listening against background noise. This study investigated the speech perception skills of young children with and without language difficulties. A speech discrimination task, using non-word minimal pairs in an XAB paradigm, was presented to 20 5- to 7-year-old children with language difficulties and 33 typically-developing (TD) children aged between 4- to 7-years. Stimuli were presented in quiet and in background noise (babble), and stimuli varied in phonetic contrasts, differing in either place of articulation or presence/absence of voicing. Children with language difficulties performed less well than TD children in all conditions. There was an interaction between group and noise condition, such that children with language difficulties were more affected by the presence of noise. Both groups of children made more errors with one voicing contrast /s/z/ and there was some indication that children with language difficulties had proportionately greater difficulty with this contrast. Speech discrimination scores were significantly correlated with language scores for children with language difficulties. Issues in developing material for assessment of speech discrimination in children with LI are discussed.

Keywords: Language impairment, assessment, non-word discrimination.

Introduction
Children with language impairments (LI) are reported to have deficits in auditory processing. Tallal and Piercy’s (1973) early work indicated that children with LI were showing a deficit in processing the rapid auditory events present in speech. It has been proposed that a difficulty processing rapid auditory events may lead to unstable representations of speech sounds, which interferes with encoding and producing speech, and ultimately leads to receptive and expressive language problems (McArthur & Bishop, 2004). However, a number of studies have been unable to support this hypothesis (see Rosen, 2003 for a review). More recently, deficits in other aspects of auditory processing have been reported in children with LI such as sensitivity to sound duration and to amplitude rise time (Corriveau, Pasquini, & Goswami, 2007) and frequency discrimination of tones (Hill, Hogben, & Bishop, 2005).

Difficulties in processing speech input have also been found. Children with LI differ from typically-developing, language normal (TD) children across a range of speech perception tasks including categorical perception (Burlingame, Sussman, Gillam, & Hay, 2005; Gerrits & de Bree, 2009), non-word discrimination (Loucas, Riches, Charman, Pickles, Simonoff, Chandler, et al., 2010), consonant identification (Ziegler, Pech-Georgel, George, Alario, & Lorenzi, 2005), gated word identification (Dollaghan, 1998), categorical discrimination (Robertson, Joanisse, Desroches, & Ng, 2009), and in discrimination between consonant-vowel (CV) syllables (Uwer, Albrecht, & von Suchodoletz, 2002). It is important to note that there is heterogeneity in auditory processing and speech perception skills, some children with LI perform within the normal range on auditory processing/speech perception tasks (e.g., McArthur & Bishop, 2004; Rosen, 2003).

A significant relationship between speech perception and language development has also been demonstrated. Babies who are better able to hear differences between similar sounding words and sounds have more advanced language skills when they are 2 or 3 years of age (Benasich & Talal, 2002; Tsao, Liu, & Kuhl, 2004). Speech perception skills are also correlated with vocabulary development and receptive language in older children (Edwards, Fox, & Rogers, 2002; Vance, Rosen, & Coleman, 2009).

Given the relationship between speech perception and language in children with typical language
development, difficulties with speech perception in some children with LI may impact on their ability to make best use of language learning interventions. Assessment of these skills has potential to contribute to profiling of individual children’s speech-language processing strengths and weaknesses and aid clinical decision-making. Currently, there is a lack of sui published material for assessing speech perception in young children (see Vance et al., 2009 for a review). There are a number of issues to consider in developing assessment tasks.

Listening to speech against background noise

Children with LI have proportionately greater difficulty in listening to speech against background noise as compared to TD controls (Robertson et al., 2009; Spaulding, Plante, & Vance, 2008; Zeigler et al., 2005). The findings of Ziegler et al. (2005) are clear. Children with LI performed more poorly in identifying consonants in vowel-consonant-vowel (VCV) syllables than age-matched controls when listening in optimal (quiet) conditions but not significantly different from a younger language-age matched control group. However, when listening in background noise, the performance of children with LI were now significantly poorer than the performance of the younger language-age matched control group, as well as the age-matched controls. Robertson et al. (2009) found similar performance on categorical perception for children with LI compared to age-matched and younger controls in quiet, and significantly different performance as compared to both control groups in noise. Spaulding et al. (2008) report that pre-school children with LI are less able to recognize a target word within a phrase when listening against a white noise, relative to TD children, and perform at a similar level to TD peers when the noise is not present. This disproportional effect of background noise in the children with LI suggests that assessment of speech perception should include presentation of speech stimuli against background noise. The importance of using the background noise condition to detect any speech perception deficits that may be present is highlighted by Robertson et al. (2009, p. 755): “The inclusion of noise increases the load in the perceptual stream by reducing the strength of the signal that is being detected, relative to attendant noise. Consequently, it might draw out subtle deficits in perception not evident when noise is not present”.

Phonetic contrast

Few studies have explored whether or not children with LI find certain phonetic contrasts more difficult to perceive when compared with TD children. Initial evidence suggests that they may have more difficulty with voice contrasts, relative to place contrasts, than TD children. Ziegler et al. (2005) presented VCV stimuli (e.g., aba) with 16 different consonants in the medial consonant position. These were presented with and without a noise masker. Individual confusion matrices showed that children with LI had more confusion with voicing than with place or manner distinctions relative to age and language matched controls. The voicing deficit was exaggerated in the background noise condition. Stop consonants appear to be less readily discriminated by children with LI, whereas their performance on vowel contrasts is unimpaired (van Alphen, de Bree, Gerrits, de Jong, Wilsenach, & Wijnen, 2004). However, stimuli requiring discrimination between fricatives were not included in the study.

In typical development, some contrasts are found to be more difficult to perceive than others. Chin-nery (1985) and Hazan and Barrett (2000) report that TD children perceived plosive consonants more easily than fricative consonants. There are also indications that young children find voice contrasts more difficult to perceive than place or manner contrasts (Mani & Plunkett, 2010), although this was not the case in older children (Hazan & Barrett, 2000). Confusion matrices for young children suggest that not all voice contrasts are equally easy/difficult. Graham and House (1971) found an error rate of 52% for the contrast s/z, whereas t/d had an error rate of 13%. A similar finding of more errors in detecting voicing changes for fricatives than for plosives is also reported for adult listeners by Cole, Jakimik, and Cooper (1978). These findings taken together suggest that for young children we might expect voiced/voice-less fricative pairs to be more difficult to discriminate than other phonetic contrasts. To identify speech perception deficits in children with LI it will be important to include stimuli that are likely to present difficulty, otherwise more subtle deficits may go unnoticed. However, normative data will also be necessary to demonstrate whether a child with LI is showing more difficulty than might be expected.

Factors affecting performance on speech perception tasks

A range of factors are likely to influence the performance of children on speech perception tasks. These might include attention, memory, conceptual development, and understanding of the task (Vance et al., 2009). Coady, Kluender, and Evans (2005) suggest that poor performance on speech perception tasks for children with LI might reflect task demands rather than a speech perception deficit. They highlight the use of synthetically produced speech contrasts, high memory demands, and the effect of abstract, unfamiliar test items. Using a categorical perception task with natural tokens of familiar words and reduced memory demands, children with LI performed as well as age-matched controls in identifying stimuli, although poorer discrimination was still evident. Coady et al. (2005) hypothesize that this might not reflect difficulties with speech perception, but may arise as a result of deficits in memory, processing, or representation.
Attention has also been identified as a possible factor in performance. Moore, Ferguson, Halliday, and Riley (2008) examined responses of TD children in a frequency discrimination task and suggested that poorer performance was due to inattention, rather than an inability to discriminate frequencies. Spaulding et al. (2008) interpret the poorer performance of children with LI when listening against noise, but not in quiet, as a difficulty with sustained selective attention. Difficulties with attention have also been identified by Sutcliffe and Bishop (2005). TD children were found to have difficulty in knowing when to focus their attention in a tone identification task. Performance improved when the presentation was altered to cue the children when they needed to attend to the target tone.

However, if attention and task demands dictated performance on speech perception tasks then one might expect similar responses regardless of stimuli. Young children with LI have been shown to perform as well as controls when categorizing vowel stimuli, but not when stop consonant stimuli are used. Van Alphen et al. (2004) interpreted their finding to suggest there was a deficit for consonant perception as the participants clearly understood the task and had sufficient attention to respond appropriately to the vowel stimuli. Rosen (2003) also suggests that findings of difficulty with some stimuli and not with others negate the argument that task demands such as memory account for performance.

To ensure the child understands and is able to complete the task it may be useful to include stimuli that children would find relatively easy to discriminate. Bishop, Adams, Nation, and Rosen (2005) advocate the use of such “catch” trials to detect whether a child lacks attention or fails to understand the task. Van Donselaar (1996) reviewed the literature on sensitivity to mispronunciations of words, where one sound segment has been changed to create a non-word. Stimuli that differed by one phonetic feature were less easily detected than those that differed by two or more features. Use of stimuli that differ on two or more features might, therefore, be sui for catch trials.

Summary and rationale for current study

Given the findings that children with LI present with speech perception deficits it is important for the clinician to be able to assess these skills. There are currently few assessments sui for clinical measurement of speech perception in young children with LI (Vance et al., 2009). In developing assessment material consideration is needed as to what factors might affect performance on the task. It is also important to identify parameters that might make the task more sensitive to identifying speech perception deficits. The literature indicates that presenting speech in noise and using stimuli that differ in voicing might ensure that any deficit that is present is detected.

The study reported here aims to examine the use of a novel assessment procedure to measure speech discrimination in children with identified language difficulties. Stimuli are presented in optimal listening conditions (quiet) and in a noise condition (babble) to examine the effect of background noise. A range of stimuli allows comparison of responses using phonetic contrasts that differ on place and on voicing. Catch trials are included to explore the role of attention in task performance. Data from TD children is also collected for comparison purposes.

The following hypotheses were proposed. On the speech discrimination task, when compared to a TD control group, children with language difficulties will:

- Make more errors in optimal listening conditions (quiet).
- Make proportionately more errors when completing the task against background noise (babble).
- Make proportionately more errors with pairs of stimuli that differ by voicing rather than place.

It is also predicted that performance on the speech discrimination task will be significantly correlated with the children’s language abilities.

If attention, or other task demands limit the performance of children with LI then more errors might be made on catch trials relative to the TD group.

Method

Participants

Sixty-two children aged 4- to 7-years were recruited from schools in and around a large city in the North of England. Thirty-five of these children, aged between 4- to 7-years, had not been identified by their school as requiring special educational support for any reason. These children were assigned to the language normal group (TD). The remaining 27 were aged between 5- to 7-years and had been identified as receiving School Action Plus support or a Statement of Special Educational Needs, in accordance with the Code of Practice used in England and Wales (Department for Education and Skills, 2001), on the basis of specific language needs. Due to the lack of sufficient standardized language assessment data, a diagnosis of specific language impairment could not be confirmed; however, children who did not pass a hearing screen or who showed low non-verbal skills were eliminated from the study. The term language difficulties (LangDiff) rather than specific language impairment is used to describe this group. Information and consent letters were distributed by participating schools to parents of all pupils who met the inclusion criteria. Signed consent forms were obtained for all children who participated. The study was approved by the ethics board having jurisdiction over the study.
Materials

Hearing screen. All participants completed a hearing screen to ensure that their hearing was within normal limits at 1, 2, and 4 KHz using Home Audiometer software (TimoEsser, version 1.9). Tone stimuli were presented on a standard laptop computer through circumaural headphones and the children responded using a standard computer joystick.

Non-verbal abilities assessment. The Coloured Progressive Matrices (CPM, Raven, Court, & Raven 1986) assessment was administered to the LangDiff children to ensure they did not have significant impairment in non-verbal skills.

Language assessment. The receptive language abilities of the LangDiff children were assessed using the Test for Reception of Grammar (TROG-2, Bishop, 2003).

XAB non-word discrimination. A speech discrimination task was presented to all participants using non-published software (Speech Input Processing in Children) on a standard laptop using circumaural headphones. A non-word stimulus is presented (X), followed by two further non-word stimuli (A and B). The child identifies which of A or B matches the initial stimulus (X). The visual display contains a large spaceship at the top of the screen and two smaller spaceships below. A cartoon of an alien appears in the large spaceship and is animated to speak a non-word, e.g., /gpa/. Two aliens appear in succession in the two smaller spaceship; one says the same non-word as the first alien, /gpa/ and the other a different non-word, e.g., /atsa/. The child identifies which of the smaller aliens copied the alien above.

Stimuli

Stimuli consisted of 10 minimal pairs of non-words that were phonotactically legal within the English phonological system and differed from each other by one phonetic feature. The non-words were disyllabic with trochaic stress pattern and a vowel-consonant-vowel (VCV) structure. Three minimal pairs differed with trochaic stress pattern and a vowel-consonant-phonetic feature (i.e., an easier trial, see Appendix). As the stimuli are relatively easy to discriminate, failure to respond correctly to these items might reflect misunderstanding of the task or a lack of attention.

Conditions

Each test block was presented in quiet and against background noise. The noise condition used a 20-talker babble presented against the stimuli with a signal-to-noise ratio of +2 dB (based on the levels calculated from all three items in a trial, excluding silences). The software had a built-in facility that automatically combined and presented the stimuli at this signal-to-noise ratio.

Using standard computer equipment it was not possible to control the precise sound level of the stimuli. A comfort listening level was set. Performance when speech is presented in quiet varies little with overall level, as long as the speech is clearly audible, for audiometrically normal listeners (Simon, 1978). For speech in noise, it is the signal-to-noise ratio that is the important factor, rather than the overall sound level (Wagener & Brand, 2005).

Procedure

Each child was tested individually in a quiet area within their school. Children completed the activities in one or two sessions depending on attention levels. For the LangDiff children the CPM (Raven et al., 1986) task was presented first, according to manual instructions. Children who scored at or below the 10th percentile on this assessment took no further part in the study. LangDiff children achieving a score above this cut-off point completed the hearing test. Using the Home Audiometer software (TimoEsser, version 1.9) the children listened to stimuli through circumaural headphones and were required to move a joystick whenever they heard a sound. A familiarization phase beginning with a relatively loud tone (40 dB) was completed to ensure the children understood the task. Tones of decreasing amplitude were then presented in an adaptive procedure until two reversals had occurred. If a child failed to respond to 2 and 4 KHz tones at 25 dB or to a 1 KHz tone at 30 dB in both ears s/he was excluded from the study. For children who demonstrated acceptable hearing levels the XAB task was then introduced. Lastly, the LangDiff children completed the TROG-2 (Bishop, 2003), presented in accordance with the manual instructions.
Practical considerations at the time of data collection meant that it was not possible to use the CPM (Raven et al., 1986) and the TROG-2 (Bishop, 2003) with the TD participants. So, for the TD children, the hearing test was presented, followed by the XAB task for children with acceptable hearing levels.

The procedure for the XAB task is as follows. A verbal explanation of the task was provided at a level appropriate for each child. A practice block comprising 15 trials was completed. The stimuli presented in the practice block differed on more than one phonetic feature (Appendix). For the first five trials of the practice block an abstract drawing accompanied the non-word stimuli, identical non-words shared the same abstract drawing, providing a visual match as well as an auditory match to facilitate comprehension of the task. For the next five trials the visual stimuli only appeared if the child made an incorrect selection on the first attempt. The drawings did not appear at all for the final five trials. The program presents verbal feedback throughout; “well done” before moving onto the next trial if the child selected the correct stimulus and “try again” before the stimuli were repeated if they made an incorrect selection. Stimuli were repeatedly presented until the child selected the correct response.

Before each item the child selected a Go button, and heard a verbal prompt of “ready” or “here we go” to cue him/her to attend to the stimuli. Balloons appeared at the side of the screen to provide the child with a visual record of how many trials s/he had completed. At the end of each block an onscreen reward was presented. Each of the three test blocks, comprising 15 trials each, were presented twice (once in quiet, once against babble). The procedure was identical as for the practice block, except that there were no visual stimuli to accompany the spoken stimuli. Verbal feedback continued to be presented and stimuli were repeated until the child provided a correct response. Only the first response was scored. During pilot work using the procedure when verbal feedback was not given during the test block some children were found to pay progressively less attention to the stimuli and to make choices at random, even though they had been successful with their first responses in the practice block. Verbal feedback and repetition of incorrect stimuli were, therefore, incorporated into the test blocks to maintain attention and the incentive to make correct responses.

The order of presentation of the test blocks was randomized. Before each block the child rolled two dice. One to indicate whether block A, B, or C would be presented, and the other determined whether that block would be presented in quiet or in babble.

Results

Two TD children failed to reach the hearing threshold and were excluded from the study. Data from the remaining 33 TD children were included in the analyses. One LangDiff participant failed to reach the hearing threshold and was excluded from the study, a further four were excluded as scores on the CPM were at or below the 10th percentile. Two LangDiff participants were reluctant to take part and testing was terminated. The remaining 20 LangDiff participants completed the XAB tasks. All TD children responded correctly to at least three of the five catch trials in each condition. Three LangDiff participants failed to respond correctly to three or more of the catch trials presented in quiet and were excluded from further analyses.

Chronological age for both groups and language age equivalent for the LangDiff group are shown in Table I. The groups are well matched on chronological age with no significant difference ($t_{(48)} = .564, p = .575$). Language age was derived from the scores on the TROG-2 (Bishop, 2003) for the LangDiff group. The language age for this group was significantly lower than chronological age ($t_{(16)} = 8.514, p < .001$). TD children did not complete the language assessment, and language age was assumed to be equivalent to chronological age. It, therefore, follows that there is a significant difference in language age between the groups, the TD group having a greater language age than the LangDiff group. Within the LangDiff group some children scored within the normal range on the receptive language assessment used, TROG-2. A commonly-used criterion for language impairment would be obtaining a score more than one standard deviation below the mean on a language assessment (i.e., below percentile rank 16) (Records & Tomblin, 1994). Five LangDiff participants achieved a score above the 16th percentile and might be considered to show language within the normal range on this task.

Speech perception performance

Distribution of percentage correct responses for the XAB task across all participants in all conditions is skewed, revealing a ceiling effect in the data, with 20 participants scoring above 95% correct (Figure 1). This effect is most apparent in the TD participants who account for 18 of those high-scoring participants.

Descriptive statistics summarizing percentage of correct responses for the TD group and the LangDiff group are shown in Table II. Use of percentage correct allows comparison between sets of stimuli that differ in voicing (two consonant pairs), and in place of articulation (three consonant pairs). The TD group achieved a higher percentage of correct responses across all conditions compared to the LangDiff group. Visual inspection of data suggests the presence of babble did not affect performance of the TD group, but had a detrimental effect on performance of the LangDiff group. Across both groups, participants were more accurate in discrimination.
when the distinguishing feature was a place contrast rather than a voice contrast, although this difference was small.

The data from the LangDiff group was more variable than that from the TD group (Table II). Due to the non-normal distribution of the data and non-homogenous variability across groups, hypotheses have been tested using non-parametric statistics. Effect sizes for the non-parametric analyses were calculated using the z-score, as advocated by Rosenthal (1991, cited in Field, 2005). Cohen (1992, cited in Field, 2005) suggests that the resulting statistics are interpreted as follows: $r = .1$, small effect; $r = .3$, medium effect; $r = .5$, large effect.

Language and speech discrimination

Performance on the speech discrimination task is significantly correlated with language age ($r = .551$, $p < .001$). Children with better-developed language skills responded more accurately. Within the LangDiff group, a moderate significant relationship between language ability, measured by TROG-2, and speech discrimination skill is revealed ($r = .585$, $p = .014$). This relationship is significant both when stimuli are presented in quiet ($r = .626, p = .007$) and in babble ($r = .514, p = .035$). LangDiff children with higher scores on the language task performed more accurately on the speech discrimination task.

Group differences on speech discrimination

The LangDiff group performed less well on the speech discrimination task than TD children (see Table II). This difference is significant (Mann-Whitney $U = 118, p = .001$), with a large effect size ($r = .50$). This significant difference was observed when scores in optimal listening conditions (quiet) were compared ($U = 148, Z = 2.728, p = .006$) with a medium effect size ($r = .41$). Removing the five participants who achieved a score on TROG-2 that was above the 16$^{th}$ percentile (i.e., within normal limits) resulted in the effect of group increasing, ($U = 60, p < .001$, effect size $r = .53$).

Boxplots (Figure 2) demonstrate some overlap in the range of performance. Some individual TD children perform similarly to the LangDiff group and some LangDiff children perform within the range of the TD children on the speech discrimination task. This overlap is not entirely explained by differences in language age. Figure 3 shows that some individuals with LangDiff with a language age of 4 years (the lowest age equivalent obtainable on the TROG2) have speech perception scores within the range of the TD group, who are assumed to have higher language ages. Some individuals in the TD group with higher language age perform poorly on speech perception.

Effect of background noise

There was no significant effect of babble across the whole data set (Wilcoxon $Z = 1.48, p = .124$). However, Table II suggested performance of the LangDiff group is more affected by babble than in the TD group. The LangDiff group performed significantly less well in babble ($Z = -2.28, p = .023$), with a strong effect size ($r = .56$), but there is no significant effect of babble for TD children ($Z = -1.72, p = .864$). As the data was not suitable for parametric analysis the size of this interaction between group and condition (see Figure 4) could not be established.

Effect of stimuli—phonetic contrast

There was no overall effect of phonetic contrast on performance ($Z = 1.54, p = .124$). However, visual inspection of the data indicate that children made fewer correct responses to the /s z/ contrast than any other contrasts, including the /t d/ contrast which also differs only on the presence or absence of voicing (Table III). Analyses were carried out to compare the /s z/ contrast with other stimuli.
Table II. Mean (SD) of percentage correct responses for each condition in each group.

<table>
<thead>
<tr>
<th>% Correct</th>
<th>TD group (n = 33) M (SD)</th>
<th>LangDiff group (n = 20) M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>88.86 (12.22)</td>
<td>72.5 (16.05)</td>
</tr>
<tr>
<td>Quiet</td>
<td>88.86 (13.68)</td>
<td>75.59 (15.55)</td>
</tr>
<tr>
<td>Babble</td>
<td>88.86 (12.41)</td>
<td>69.41 (18.04)</td>
</tr>
<tr>
<td>Voice contrasts</td>
<td>87.59 (15.10)</td>
<td>70.77 (15.93)</td>
</tr>
<tr>
<td>Place contrasts</td>
<td>89.71 (11.01)</td>
<td>73.65 (16.84)</td>
</tr>
<tr>
<td>Voice contrasts in quiet</td>
<td>86.74 (17.1)</td>
<td>74.63 (15.06)</td>
</tr>
<tr>
<td>Voice contrasts in babble</td>
<td>88.44 (14.92)</td>
<td>66.91 (20.1)</td>
</tr>
<tr>
<td>Place contrasts in quiet</td>
<td>90.28 (12.31)</td>
<td>76.23 (17.60)</td>
</tr>
<tr>
<td>Place contrasts in babble</td>
<td>89.14 (12.54)</td>
<td>71.08 (18.13)</td>
</tr>
</tbody>
</table>

TD, typically-developing group; LangDiff, language difficulties group.

Figure 2. Boxplots showing range of scores within the typically-developing (TD) and language difficulties (LangDiff) groups on the speech perception task across all conditions. Participants 12 and 23 show as outliers with speech perception scores below the quartile range.

Table III. Percentage correct responses to each stimuli contrast.

<table>
<thead>
<tr>
<th>Contrast</th>
<th>TD group (n = 33) Mean % correct (SD)</th>
<th>LangDiff group (n = 20) Mean % correct (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/s z/</td>
<td>86.17 (17.86)</td>
<td>65.44 (17.69)</td>
</tr>
<tr>
<td>/t d/</td>
<td>89.58 (15.60)</td>
<td>76.10 (18.25)</td>
</tr>
<tr>
<td>/f s/</td>
<td>88.45 (12.61)</td>
<td>75.00 (19.14)</td>
</tr>
<tr>
<td>/p t/</td>
<td>90.90 (10.49)</td>
<td>72.43 (17.68)</td>
</tr>
<tr>
<td>/s ß/</td>
<td>89.77 (12.87)</td>
<td>73.53 (20.20)</td>
</tr>
</tbody>
</table>

TD, typically-developing group; LangDiff, language difficulties group.

Table IV. Statistical analysis of comparisons between /s z/ contrast and the other contrasts.

<table>
<thead>
<tr>
<th>Contrast</th>
<th>TD group (n = 33) Mean % correct (SD)</th>
<th>LangDiff group (n = 20) Mean % correct (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/s z/ vs /t d/</td>
<td>Wilcoxon 2.797 (.005)</td>
<td>/s z/ vs /f s/</td>
</tr>
<tr>
<td>/s z/ vs /p t/</td>
<td>Wilcoxon 2.838 (.005)</td>
<td>/s z/ vs /s ß/</td>
</tr>
</tbody>
</table>

Indicates differences that are still significant when Bonferroni correction is applied.

Responses to the /s z/ contrast were significantly less accurate than responses to /t d/ , /p t/, and /s ß/ contrasts when Bonferroni correction is applied (see Table IV). Responses to /s z/ were not significantly different from responses to the /f s/ contrast when Bonferroni correction is applied.

Visual inspection of the data suggests that there is an interaction between group and type of contrast. Figure 5 indicates a greater difference between percentage correct responses to /s z/ contrasts as compared to the other four contrasts in the LangDiff group, than in the TD group where this difference is less. Repeating Wilcoxon analyses for the TD group showed no significant difference between the /s z/ contrast and each other contrast.
Assessing speech perception in children

TD, typically-developing group; LangDiff, language difficulties group.

LangDiff group. 9.27 (1.13); 6–10 4.64 (0.65); 3–5 4.64 (0.70); 3–5 group.

Figure 5. Interaction between group and percentage correct for each contrast. TD, typically-developing group; LangDiff, language difficulties group.

Table V. Mean (SD) and range for number of correct responses to catch trials in each group.

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 10)</th>
<th>Quiet (n = 5)</th>
<th>Babble (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD); Range</td>
<td>M (SD); Range</td>
<td>M (SD); Range</td>
</tr>
<tr>
<td>TD group</td>
<td>9.27 (1.13); 6–10</td>
<td>4.64 (0.65); 3–5</td>
<td>4.64 (0.70); 3–5</td>
</tr>
<tr>
<td>LangDiff</td>
<td>7.47 (1.70); 4–10</td>
<td>4.06 (0.75); 3–5</td>
<td>3.41 (1.33); 0–5</td>
</tr>
</tbody>
</table>

TD, typically-developing group; LangDiff, language difficulties group.

Discussion

The current study explored the use of a novel assessment procedure to measure speech discrimination skills in children aged 5- to 7-years, with and without language difficulties. The stimuli were presented in quiet and against background noise (babble). Different phonetic contrasts were presented to examine which types of stimuli might be easier or more difficult to discriminate.

The data supports previous findings that speech discrimination skills are significantly correlated with language abilities (Edwards et al., 2002; Vance et al., 2009). It confirms the hypothesis that children with language difficulties perform less well than chronologically age-matched TD children, and tightening the criteria for language level for inclusion in the LangDiff group only served to increase the difference between the two groups. This difference is present even in optimal listening conditions (quiet). Some children in the TD group performed within the range of the LangDiff group and individuals with language difficulties performed within the range of the TD group (Figure 2). Poorer performance in the LangDiff group cannot be completely explained by the difference in language age. Some individuals with low language age perform within the range of the TD group (Figure 3).

As predicted, presentation of the speech discrimination task against babble had a more detrimental effect on the performance of the LangDiff group than TD children, in common with other findings (Robertson et al., 2009; Ziegler et al., 2005). It was surprising that background noise had no significant effect on the performance of the TD children. However, many children in the TD group scored at ceiling on the task. It may be that decreasing the signal-to-noise ratio (SNR) in the babble condition would have resulted in identifiably poorer performance in noise for the TD group. However, this might have resulted in floor effects for the LangDiff group. Adaptive procedures in which the SNR is varied to measure the lowest intensity at which children can respond accurately have been used in studies of speech perception in children with dyslexia and with auditory neuropathy (Messoud-Galusi, Hazan, & Rosen, 2007; Rance, Barker, Mok, Dowell, Rincon, & Garratt, 2007). These procedures avoid floor and ceiling effects and may have a place in assessment of speech perception in noise for children with language impairment.

There are mixed findings within the literature regarding the relationship between speech perception and language impairments (Rosen, 2003). One reason for this may lie with the stimuli used. Children with LI may have more difficulty discriminating some acoustic-phonetic contrasts than others and differences in findings might reflect the choice of stimuli used. Knowledge regarding those contrasts that are more easy/difficult to discriminate will
aid in the development and interpretation of speech discrimination tasks. The data reported here initially suggests that more errors are made in discriminating voicing contrasts than place contrasts. On closer inspection it became clear that this difference arose because more errors were made on the /s z/ discrimination. Performance on the other voicing contrast pair /t d/ did not differ significantly from any other contrasts. This is consistent with Graham and House (1971), who also identified greater confusion for the contrast /s z/ than for /t d/ in young TD children. Figure 5 suggested an interaction between stimulus contrast and group, such that children with language difficulties might have relatively more difficulty with the /s z/ contrast than TD children. Ziegler et al. (2005) also found a proportionally greater difficulty with voicing contrasts for children with LI, but their study did not allow the /s z/ contrast to be specifically explored.

There are a number of limitations in this study and so conclusions can only be tentatively drawn. There are relatively few participants with LangDiff. It has been assumed that there is a difference in language age between the TD group and the LangDiff group. However, this is based on the assumption that the TD children were performing at the level of their chronological age as their receptive language was not measured. A further limitation of the study is the absence of a language-age matched control group. Many of the LangDiff group had a language age of less than 4 years. Pilot work using this speech discrimination task found performance of children under the age of 4;06 was highly variable, with some children not scoring above chance level. A language-age matched group of children aged 4 years and under would not have provided reliable data. It could, therefore, be argued that the LangDiff group performed less well on the task because their skills across a range of aspects of development are poorer than those of the TD group. Another possible explanation of the findings is that lower scores on speech perception are related to language age per se, rather than the presence of a language deficit.

However, the task was designed to address some of the concerns about task demands that have been raised in the literature. Verbal instructions were kept to a minimum and the inclusion of the visual stimuli in the practise block aided understanding. Vocabulary and concepts, such as same and different, that might be difficult for young children or children with LI to understand (Beving & Ebling, 1973, cited in Vance et al., 2009), were avoided. A verbal signal was given to alert the child to attend to the stimuli, as advocated by Sutcliffe and Bishop (2005). The inclusion of “catch” trials, with more distinct stimuli, helped to identify those children who may not have fully understood the task, or were unable to sustain attention, allowing their data to be excluded from further analyses. The data indicates that the LangDiff group made more errors on catch trials than the TD group. It is possible that some children might be experiencing marked difficulties with speech perception such that they do not hear the difference between the catch trial items. If this is the case it would be useful to have catch trials that consisted of sounds that were not words, perhaps recordings of animal sounds. Poorer performance on the catch trials may also indicate less consistent attention to the task, or less understanding of task requirements. Moore et al. (2008) also suggest that poorer performance on auditory perception tasks might reflect lack of attention. However, within both the TD and LangDiff groups there is the same differential performance on different acoustic-phonetic contrasts which suggests that poorer attention is not the only reason why some responses are incorrect (Rosen, 2003).

If some children with language impairments are experiencing difficulties with speech perception it is important for clinicians to measure these skills when profiling a child’s speech and language skills. Assessment should use tasks, conditions, and stimuli that will allow even subtle difficulties in speech perception to be measured. This study suggests that use of background noise and of the contrast /s z/ would be most taxing of speech discrimination skills. However, children’s performance should be evaluated holistically to establish whether poor performance arises from inconsistent or less-sustained attention, or other factors, or reflects the presence of a speech perception deficit. This paper highlights some of the issues to be considered in developing suitable assessment procedures that can be carried out in a school or clinic setting with children with language impairments.

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References


Appendix

Practice stimuli

Six pairs presented twice each and one pair (/fɔl-/gɔl/) presented three times in practice block.

<table>
<thead>
<tr>
<th>/aʊə/</th>
<th>/aʊə/</th>
<th>/nɔʃ/</th>
<th>/ŋpʃ/</th>
<th>/dʌp/</th>
<th>/dʌp/</th>
<th>/ædə/</th>
<th>/æzə/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tʃə/</td>
<td>/tʃə/</td>
<td>/tʃəb/</td>
<td>/tʃəb/</td>
<td>/tʃəb/</td>
<td>/tʃəb/</td>
<td>/tʃəb/</td>
<td>/tʃəb/</td>
</tr>
</tbody>
</table>

Catch trial stimuli

Differing on two or more features, each pair presented once across the three blocks in each condition.

<table>
<thead>
<tr>
<th>/ɪfə/</th>
<th>/ɪdə/</th>
<th>/ɪpəs/</th>
<th>/ɪzəl/</th>
<th>/ʌdəs/</th>
<th>/ʌdəs/</th>
<th>/ʌdəs/</th>
<th>/ʌpəs/</th>
</tr>
</thead>
</table>

Test stimuli

Each pair presented four times across three blocks in each condition.

<table>
<thead>
<tr>
<th>Voice fricative contrast</th>
<th>Voice plosive contrast</th>
<th>Place fricative contrast</th>
<th>Place fricative contrast</th>
<th>Place plosive contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>/æsə/</td>
<td>/æzə/</td>
<td>/æsə/</td>
<td>/æsə/</td>
<td>/æsə/</td>
</tr>
<tr>
<td>/səs/</td>
<td>/səz/</td>
<td>/səs/</td>
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