Speech Reading and Learning to Read: A Comparison of 8-Year-Old Profoundly Deaf Children With Good and Poor Reading Ability

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Nine children with severe-profound prelingual hearing loss and single-word reading scores not more than 10 months behind chronological age (Good Readers) were matched with 9 children whose reading lag was at least 15 months (Poor Readers). Good Readers had significantly higher spelling and reading comprehension scores. They produced significantly more phonetic errors (indicating the use of phonological coding) and more often correctly represented the number of syllables in spelling than Poor Readers. They also scored more highly on orthographic awareness and were better at speech reading. Speech intelligibility was the same in the two groups. Cluster analysis revealed that only three Good Readers showed strong evidence of phonetic coding in spelling although seven had good representation of syllables; only four had high orthographic awareness scores. However, all 9 children were good speech readers, suggesting that a phonological code derived through speech reading may underpin reading success for deaf children.

Although the great majority of children who are born with or acquire a profound hearing loss in the first year of life experience considerable difficulty in learning to read (Marschark & Harris, 1996; Musselman, 2000) and write (Singleton, Morgan, DiGello, Wiles, & Rivers, 2004), a small number become highly proficient. Relatively little research has been carried out on these children and, in part, this is because there are relatively few. In a longitudinal study of beginning readers (Harris & Beech, 1998), only 4 children out of 24 were reading at a level comparable to hearing peers after 2 years of reading instruction; and in a later study, using a different cohort, only 6 children out of 29 had a reading age within 6 months of their chronological age of 8 years (Harris & Moreno, 2004). As Marschark and Harris (1996) note, this low proportion of deaf children who learn to read successfully has been consistently reported since the first systematic assessments were carried out in the United States (DiFrancesca, 1972) and the United Kingdom (Conrad, 1979).

What evidence is there about how deaf children become successful readers? A useful starting point is to consider how the majority of children (i.e., those who are hearing) learn to read. A common view is that learning to read for hearing children draws heavily upon spoken language skills, especially phonological awareness. The prevalence of this view is captured in a recent review (Castles & Coltheart, 2004) that documents 44 longitudinal studies examining the relationship between phonological awareness and learning to read. As Castles and Coltheart (2004) argue, there remains considerable uncertainty about how the various aspects of phonological awareness and phonological coding are related to each other, and to reading success. However, there is agreement about one key aspect of learning to read:

There is a vast amount of educational and psychological research to suggest that knowledge about letter–sound correspondences is a primary building block to reading, providing children with the tools...
to sound out new words and assisting with the
formation of lexical representations. (Castles &
Coltheart, 2004)

One possibility is that deaf children who have good
phonological awareness and good phonological coding
skills can learn to read in the same way as hearing
children by developing their knowledge about letter-
sound correspondences. A number of studies have
shown that phonological awareness and phonological
coding skills are strong predictors of reading success
among deaf children (Dyer, MacSweeney, Szcerbinski,
Green, & Campbell, 2003; Harris & Beech, 1998; Harris
& Moreno, 2004). This relationship holds even though
deaf children, as a group, show less evidence of phono-
logical coding than hearing peers (Beech & Harris,
1997; Burden & Campbell, 1994; Harris & Beech,
1998; Harris & Moreno, 2004; Leybaert & Alegria,
1995; Merrills, Underwood, & Wood, 1994; Nielsen &
Luetke-Stahlman, 2002; Waters & Doehring, 1990).
Taken together, these studies suggest that good deaf
readers are likely to have better phonological coding
skills than deaf children who are poor readers. However,
Harris and Beech (1998) found that this was not the case
for all 4 good readers in their sample, and they report
that two different profiles were evident. The best reader,
who did not sign, had good spoken English and did well
on a test of phonological awareness; however, the child
with the second highest score was a native signer (of
Deaf parents) who had poor phonological skills; and of
the other 2 good readers, one showed the first pattern
and one, the second. Harris and Beech conclude, “The
presence of these two contrasting profiles underlines
the fact that deaf children may become successful
readers by more than one route” (p. 214).

Comparisons of the reading strategies of orally
educated children and those whose preferred language
is sign (Miller, 2002) suggest that communication
mode has a profound effect on the extent to which
children who are deaf make use of phonological coding
in reading. Miller (2002) argues that children who are
native signers do not engage in phonological recoding.
At the same time, some authors have claimed that
knowledge of a sign language (usually American Sign
Language [ASL]) promotes the development of read-
ing and spelling (Wilbur, 2000) and that deaf children
with high levels of proficiency in ASL have higher
levels of English literacy than peers of similar IQ but
with lower levels of ASL (Strong & Prinz, 1997).
However, it is not clear exactly how good signing pro-
motes good reading, especially in the early stages of
learning to read, and an authoritative review of lit-
eracy attainment in deaf children who sign (Goldin-
Meadow & Mayberry, 2001) concludes that skill in
signing does not guarantee skill in reading. Goldin-
Meadow and Mayberry (2001) point to the need for
researchers to uncover how deaf readers could map
their knowledge of sign onto print.

Although it has been suggested that early exposure
to sign is an important factor in educational achieve-
ment (Schlesinger & Meadow, 1972), more recent re-
search suggests that deaf children learn to read best
when they are exposed to both signing and oral lan-
guage (see Marschark & Harris, 1996, for a review).
The suggestion is that good signing skills provide chil-
dren with a secure language base, whereas knowledge of
the oral language provides them with an understanding
of the sounds that occur in the words they will encour-
ter in reading. If this is the case, then we would expect
to see that successful deaf readers share certain skills
in common and that, rather than there being two dis-
tinct routes to reading success for deaf children, there
might be a single route in which certain components
have more or less emphasis in individual children.

The aim of this study was to identify the skills of
good deaf readers. We did this by making a direct
comparison between good and poor deaf readers,
selected from a larger sample, in order to discover
how their reading-related skills differed. A number of
comparison measures were used. The first two, which
looked directly for evidence of phonological coding in
spelling, were percentage of phonetic errors and per-
centage of errors in which the number of syllables was
correctly represented. The other measures were ortho-
graphic awareness, speech intelligibility, and accuracy
in speech reading.

There was a clear rationale for the inclusion of each
of these measures. The percentage of phonetic spelling
errors was designed to uncover how much deaf chil-
dren were aware of the sounds in words that they could
not spell accurately. When hearing children attempt to
spell an unfamiliar word in an irregular orthography
such as English, where a sound may be spelled in a number of different ways, they often choose the correct sound but select an incorrect way of spelling it as in PLAD for plaid or BRUTR for brother (Trieman, 1998). Deaf children, as a group, show a different pattern. French-speaking 11-year-old deaf children made few phonetic spelling errors even though hearing French children commonly produce such errors (Leybaert & Alegria, 1995), and a similar pattern has emerged from studies of English (Padden, 1993; Sutcliffe, Dowker, & Campbell, 1999). Sutcliffe et al. (1999) found that deaf children frequently omitted consonants—a pattern that was seldom seen in the spelling of the hearing children. Analysis of the spelling errors produced by deaf adults (Olson & Caramazza, 2004) also shows that the majority are phonologically implausible although orthographically legal (e.g., MEDINCE for medicine and SUBITUSE for substitute). We expected Good Readers to produce more phonetic errors than Poor Readers.

The second spelling measure was also concerned with the representation of sound but at the syllabic rather than the phonemic level. Our interest in this level of representation followed from the claim that deaf children have syllabic knowledge at a level comparable to hearing children of the same reading age (Sterne & Goswami, 2000). If this is the case, we might expect to find that Good Readers are able to correctly represent the number of syllables that occur in a word they cannot spell correctly even though they may not be aware of individual phonemes.

The orthographic awareness test was designed to see whether Good Readers had a better grasp of English orthography than Poor Readers. Deaf adults respect the rules of orthography in spelling (Olson & Caramazza, 2004); and performance on a task, in which children have to discriminate between legal and illegal letter strings, significantly predicted the reading level for both 8- and 14-year-old deaf children (Harris & Moreno, 2004). We therefore predicted that Good Readers would score more highly on orthographic awareness than Poor Readers.

We also included a rating of speech intelligibility because some previous studies have shown that deaf children with more intelligible speech become better readers (Harris & Beech, 1998; Leybaert & Alegria, 1995). However, because at least some children with good signing skills but relatively poor oral skills become good readers (Strong & Prinz, 1997; Wilbur, 2000), it was important to assess this measure.

The final measure was accuracy in silent speech reading (also known as lipreading). A number of authors have claimed that deaf children can acquire a phonological code through speech reading (Alegria, 1998; Alegria, Charlier, & Mattys, 1999; Campbell, 1997; Campbell & Burden, 1994; Dodd, 1980). However, lip patterns are often ambiguous and some sounds (e.g., the bilabials /b, m, p/) are almost impossible to distinguish on lip pattern alone. Speech reading thus provides, at best, an impoverished version of the code that hearing children have when they first learn to read.

Studies of Cued Speech (CS)—a system that uses hand shapes made near the mouth to disambiguate sounds with the same lip pattern—have found that CS can improve deaf children’s ability to lip-read at least in French (Alegria, 1998; Alegria et al., 1999).1 Deaf children who receive CS from an early age are able to make decisions about whether words rhyme at a level comparable to hearing peers (Leybaert & Charlier, 1996) even when spelling cannot be used as a guide as in tasse-glace. This contrasts with deaf children, not exposed to CS, who find rhyme judgments very difficult (Harris & Beech, 1998). A recent study (Alegria & Lechat, 2005) has shown that deaf children integrate information from cues and lip patterns when they perceive words, and this supports the idea that the additional information provided by the cues is being used to produce finer discriminations. Although none of the children in this study had been exposed to CS (which is not commonly used in the United Kingdom), we expected that they would vary considerably in their speech reading ability (Dodd, McIntosh, & Woodhouse, 1998). If speech reading can be used to develop a phonological code, we would expect to find that Good Readers were better at speech reading than Poor Readers.

Method

Participants

The Good and Poor Readers were selected from an initial cohort of 29 deaf children described in Harris...
and Moreno (2004). The children were aged between 7 and 8 years at initial assessment and were recruited from a total of 10 schools and units for deaf children of primary school age. All had an unaided hearing loss of at least 85 dB in the better ear and a nonverbal IQ above 85, assessed using the Matrices, Recall of Designs, and Block Design tests from the revised British Ability Scales II (BASII) (Elliott, Smith, & McCulloch, 1996). Although there was wide variation in educational regime, most children used Total Communication in the classroom in which spoken English and Signed English were used together. The signing skills of the children were very variable, with a small number being fluent users of British Sign Language (BSL). However, it is notable (see Table 7) that 5 children in the Good Reader group had BSL as their first language, whereas this was true of only one child in the Poor Reader group.

At initial assessment, the children were tested for reading using the single-word reading test from BASII. Children chose either to read aloud or sign or use a mixture of both when producing their responses, and in the case of oral responses, children were not penalized for pronunciation. Nine children were identified as Good Readers in that they were reading within 10 months of their chronological age (see Table 7 for individual lags). Nine children were identified as Poor Readers in having a reading lag of at least 15 months below chronological age. In the worst case the delay was 31 months behind chronological age and in the best it was 15 months. There was a highly significant difference between the mean reading age of the two groups, which was 96 months (8;0) for the good readers and 70 (5;10) months for the poor readers (see Table 1). The two groups did not differ in chronological age, nonverbal IQ, or unaided hearing loss (see Table 1) and both comprised children who were native users of BSL as well as those with poor signing skills (see Table 7).

Assessments

Reading comprehension. In addition to the single-word reading test used for initial screening, children were also given the Neale analysis of reading ability (Neale, 1989) to assess their level of reading comprehension.

Spelling test. The spelling test was as reported in Harris and Moreno (2004) and consisted of 39 line drawings of familiar objects. Children were asked to spell the name of each picture in turn. Items were selected to produce a large number of spelling errors so that, in addition to some common monosyllabic regular words such as car and fish and some monosyllabic irregular words (e.g., eye and door), there were several multisyllabic items such as television, aeroplane, telephone, giraffe, and squirrel. Incorrect spelling was classified as containing a phonetic error if at there was at least one instance where a sound was incorrectly represented by a letter or letters that sounded correct (e.g., BATERRE, BATTARY, BATRY, BATIRY, BACHREY were all classed as phonetic errors).

In addition to phonetic errors, incorrect spellings were classified according to whether or not a child attempted to represent the number of syllables of the target word. Thus spellings such as JRAFF, DARAFE, and JRUF were classed as containing two syllables (like giraffe) but GITF, DRUF were not.

For both classifications, there were two independent raters. Cases of disagreement were infrequent, but where they occurred, there was an agreed classification for each item.

Orthographic awareness test. Full details of this task can be found in Harris and Moreno (2004) where data

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean (SD) of hearing loss, nonverbal IQ, chronological age, and single-word reading age for Good and Poor Readers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good Readers</td>
</tr>
<tr>
<td>Unaided hearing loss</td>
<td>103.53 dB (12.19)</td>
</tr>
<tr>
<td>Nonverbal IQ</td>
<td>108.22 (13.73)</td>
</tr>
<tr>
<td>Age in months</td>
<td>98.78 (7.46)</td>
</tr>
<tr>
<td>Reading Age</td>
<td>96.11 (9.21)</td>
</tr>
</tbody>
</table>

*Indicates significance at the .001 level (two tailed).
for the original cohort are reported. The task (Siegel, Share, & Geva, 1995) presents children with legal and illegal letter strings and asks the child to choose the legal one. Illegal strings contained a bigram that never occurs in English in a given position as in filv. In order to make the task appealing to children we used pictures of aliens and, through a series of training trials, explained that the idea was to distinguish between a name that seemed very strange (illegal strings) and one that seemed like an English name (legal string). There were then 17 trials, each with four items in which one was a legal string and the others were illegal.

**Speech intelligibility.** The Speech Intelligibility Rating, developed for the evaluation of cochlear implantation in children (Allen, Nokolopoulos, Dyar, & O’Donoghue, 2001), was used to assess intelligibility. The scale has five categories, ranging from connected speech being intelligible to all listeners to no words being intelligible even to someone familiar with the child (see Table 2). The second author (who was very familiar with the children and could speech read) carried out an initial rating. Then an independent rater, who was not familiar with the speech of deaf children, carried out rating from videorecordings made during initial assessment. In most cases, the two raters awarded the same category but, if they did not, the rating of the inexperienced rater was used to assign Categories 4 and 5 because these require intelligibility by all listeners rather than someone who is familiar with the children.

**Speech reading.** Speech reading ability was assessed by a test, devised by the authors, in which children were presented with a set of pictures from which they had to select one that corresponded to a word or phrase being pronounced by a female speaker on a silent videorecording. There were five blocks of single words, involving discriminations of increasing difficulty (Geers, 1994). In the first block, items differed in number of syllables as well as onset and rime (e.g., *fish, baby, birthday cake*); and in the second block all items were two syllables long but still differed in onset and rime (e.g., *flower, sandwich, carrot*). Blocks 3, 4, and 5 were considerably more difficult in that all words were monosyllabic. In Block 3, words had the same onset (e.g., *boat, ball, book*) and, in Blocks 4 and 5, they all had the same rime (e.g., *hair, square, chair* in Block 4 and *tree, knee, ski* in Block 5). There were 10 items to speech read in each block with some being taken from Geers (1994) and others chosen by the authors. Each word was pronounced twice, and children pointed to the correct picture after hearing each word. In each block, some items were repeated so that the child could not exclude pictures that had previously been chosen.

The final part of the speech reading test was an adaptation of the early part of the Verbal Comprehension test from the British Ability Scales (Elliott et al., 1996). This involves presentation of simple commands and questions involving a picture and a set of toys. As for the single words, each item was pronounced twice and responses were scored as correct if children responded appropriately. (See Appendix for a list of the items used in the speech reading test.)

**Procedure.** All testing was carried out individually in the child’s school. The tests of reading comprehension, spelling, and orthographic awareness tests were administered several weeks after the initial screening. The speech reading test was administered in follow-up testing that took place within 1 year of initial assessment.

<table>
<thead>
<tr>
<th>Category</th>
<th>Speech intelligibility description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Connected speech is intelligible to all listeners. The child is understood easily in everyday contexts</td>
</tr>
<tr>
<td>4</td>
<td>Connected speech is intelligible to a listener who has had little experience of a deaf person’s speech. The listener does not need to concentrate unduly</td>
</tr>
<tr>
<td>3</td>
<td>Connected speech is intelligible to a listener who concentrates and lip-reads within a known context</td>
</tr>
<tr>
<td>2</td>
<td>Connected speech is unintelligible. Intelligible speech is developing in single words when context and lipreading cues are available</td>
</tr>
<tr>
<td>1</td>
<td>No words can be recognized</td>
</tr>
</tbody>
</table>

Table 2  Speech Intelligibility Rating (Allen et al., 2001)
Results

In order to establish that the difference between the Good and Poor Readers extended beyond the domain of single-word reading, scores for the two groups were compared on the Neale test and the spelling test (see Table 3). It can be seen that there was considerable difference between the two groups on both measures with the good readers scoring more highly. On the Neale test, none of the Poor Readers scored below the cutoff point, whereas all the Good Readers did so. This difference was highly significant \((t_{16} = 5.03, \ p = .001)\). The difference between scores on the spelling test was also highly significant \((t_{16} = 4.83, \ p < .001)\).

Table 4 shows the intercorrelation of the five measures that we used, controlling for nonverbal IQ. The partial correlation matrix shows significant correlations between the percentage of phonetic errors and both correct representation of syllables \((r = .80, \ p < .001)\) and orthographic awareness \((r = .46, \ p = .049)\). Speech reading was also significantly correlated with phonetic errors \((r = .51, \ p = .025)\), and the correlations with both orthographic awareness \((r = .44, \ p = .059)\) and syllabic representation \((r = .44, \ p = .058)\) approached significance. Speech intelligibility was not, however, correlated with any of the other measures.

Because phonetic errors and speech reading were correlated with each other and with the other measures, hierarchical regression was used to compare their relationship to reading. Two forced-entry regression analyses were carried out, with phonetic errors and speech reading as the predictor variables and reading lag (in months) as the dependent variable. The results are summarized in Table 5 where it can be seen that speech reading remained a significant predictor even after percentage of phonetic errors was entered as the first term, whereas the same did not hold when phonetic errors was entered as the first term and speech reading as the second.

Table 6 shows the mean scores of the Good and Poor Readers on each measure. It can be seen that Good Readers made significantly more phonetic errors and were more accurate at representing syllables than Poor Readers. They also had higher scores in the tests of orthographic awareness and speech reading (both for single words and for sentences). Independent \(t\) tests revealed that all these differences were significant at \(p \leq .01\) (see Table 6 for \(t\) values). Speech intelligibility ratings were, however, identical for the two groups.

At first sight, these results imply that Good Readers differed from Poor Readers on every measure except speech intelligibility. However, there was wide individual variation even for the four measures where there were clear group differences: phonetic errors ranged from 0% to 40%, correct representation of syllables from 25% to 89%, orthographic awareness scores from 4 (below chance) to 11, and speech reading scores from 35 to 43. (See Table 7 for individual scores of Good Readers and Poor Readers.)

In order to shed further light on individual scores, \(k\)-means cluster analyses (using two clusters, Group 1 = higher scores, Group 2 = lower scores) were performed.

### Table 3

<table>
<thead>
<tr>
<th>Measure</th>
<th>Good Readers</th>
<th>Poor Readers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neale test, age in months</td>
<td>75.11 (9.54)</td>
<td>59.11 (0.33)</td>
</tr>
<tr>
<td>Spelling test</td>
<td>16.22 (5.96)</td>
<td>4.22 (4.50)</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Measure</th>
<th>Phonetic errors</th>
<th>Correct syllables</th>
<th>Orthographic awareness</th>
<th>Speech intelligibility</th>
<th>Speech reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonetic errors</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct syllables</td>
<td>.80** ((p &lt; .001))</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthographic awareness</td>
<td>.46* ((p = .049))</td>
<td>.23 ((p = .34))</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech intelligibility</td>
<td>.33 ((p = .17))</td>
<td>.17 ((p = .49))</td>
<td>.16 ((p = .53))</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Speech reading</td>
<td>.51* ((p = .025))</td>
<td>.44(*) ((p = .058))</td>
<td>.44(*) ((p = .059))</td>
<td>.38 ((p = .108))</td>
<td>1.0</td>
</tr>
</tbody>
</table>

(*)Indicates significance between the .05 and .06 level (two tailed).
*Indicates significance at the .05 level (two tailed).
**Indicates significance at the .01 level (two tailed).
on each measure, except speech intelligibility, to see whether it could reliably distinguish Good and Poor Readers. Cluster analyses of this kind are appropriate when the number of groups is small and is known a priori (Beauchaine & Beauchaine, 2002).

For phonetic errors, all children assigned to Group 1 (n = 3, cluster center = 33.44) were Good Readers, but Group 2 (n = 15, cluster center = 3.60) contained 6 Good Readers as well as all the Poor Readers. The percentage of correct representation of syllables produced two equally sized clusters: Group 1 (n = 9, cluster center = 58.05) contained 7 Good Readers and 2 Poor Readers and Group 2 (n = 11, cluster center = 3.73), 4 Good Readers, and 7 Poor Readers. For speech reading, the division was Group 1 (n = 15, cluster center = 36.60) and Group 2 (n = 3, cluster center = 19.33). This pattern was rather different from the other measures in that all the Good Readers were assigned to Group 1 as well as 6 of the Poor Readers.

Discussion
The aim of this research was to identify characteristics of children who are prelingually, profoundly deaf but who, nevertheless, learn to read successfully. Before discussing the findings, it is important to note that the two groups of children that we identified differed not only in single-word reading but also in their ability

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>p</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td></td>
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</tr>
<tr>
<td>Speech reading</td>
<td>−.98</td>
<td>.26</td>
<td>−.69</td>
<td>.002**</td>
<td>.47</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech reading</td>
<td>−.70</td>
<td>.31</td>
<td>−.49</td>
<td>.04*</td>
<td>.54</td>
</tr>
<tr>
<td>Phonetic errors</td>
<td>−.27</td>
<td>.18</td>
<td>−.33</td>
<td>&gt;.05</td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
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<td></td>
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<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonetic errors</td>
<td>−.52</td>
<td>.17</td>
<td>−.62</td>
<td>.006**</td>
<td>.38</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonetic errors</td>
<td>−.27</td>
<td>.18</td>
<td>−.33</td>
<td>.16</td>
<td>.54</td>
</tr>
<tr>
<td>Speech reading</td>
<td>−.70</td>
<td>.31</td>
<td>−.49</td>
<td>.04*</td>
<td></td>
</tr>
</tbody>
</table>

*Indicates significance at the .05 level (two tailed).

**Indicates significance at the .01 level (two tailed).

Table 5  Summary of hierarchical regression analyses for variables predicting reading lag

Table 6  Mean (SD) of percentage phonological errors and correct representation of syllables in spelling, orthographic awareness and speech reading for Good and Poor Readers

<table>
<thead>
<tr>
<th></th>
<th>Good Readers</th>
<th>Poor Readers</th>
<th>t₁₆₀</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonetic errors in spelling,%</td>
<td>16.22 (14.94)</td>
<td>0.93 (2.78)</td>
<td>3.02</td>
<td>.01**</td>
</tr>
<tr>
<td>Representation of syllables,%</td>
<td>53.23 (20.42)</td>
<td>23.91 (19.85)</td>
<td>3.09</td>
<td>.004*</td>
</tr>
<tr>
<td>Orthographic awareness score</td>
<td>6.33 (4.00)</td>
<td>2.03 (2.98)</td>
<td>2.59</td>
<td>.01*</td>
</tr>
<tr>
<td>Speech intelligibility rating</td>
<td>2.33 (1.58)</td>
<td>2.33 (1.41)</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Speech reading score (words)</td>
<td>38.89 (2.57)</td>
<td>28.56 (7.68)</td>
<td>3.83</td>
<td>.002**</td>
</tr>
<tr>
<td>Speech reading score (sentences)</td>
<td>7.22 (1.48)</td>
<td>4.77 (1.92)</td>
<td>2.11</td>
<td>.004*</td>
</tr>
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</table>

*aFor these comparisons, equal variances were not assumed.

*Indicates significance at the .01 level (one tailed).
to read text and to spell. We were thus comparing two carefully matched groups of similar chronological age that had extensive difference in reading and spelling.

The five measures we chose for comparison were selected because they assessed a number of different skills that had been previously identified as potentially important for reading success in deaf children. Five of the measures—phonetic errors, syllabic representation, orthographic awareness, and speech reading of words and sentences—were significantly higher for Good Readers than Poor Readers. Only one measure—speech intelligibility—was not. As can be see in Table 6, Good Readers had ratings that ranged from 5 (all words intelligible) to 1 (no words intelligible). The children in our sample did not, therefore, show the pattern reported in other studies of a link between speech intelligibility and reading success (Harris & Beech, 1998; Leybaert & Alegria, 1995). It is worth noting, that this failure to find a difference in intelligibility between the two groups is unlikely to be because our measure was not discriminating since Harris and Beech (1998) used only a 3-point scale.

The pattern of intercorrelations among measures suggests that they were tapping skills with common components. Not surprisingly, the highest correlation (.80) was between the two measures of phonological coding in spelling—phonetic errors and syllabic representation. In part, the strength of this correlation lies in the fact that both measures were derived from spelling errors. Nevertheless, it also seems likely that the two measures reflected a common encoding ability because representation of sounds at both the phonemic and the syllabic level requires a good knowledge of letter–sound correspondences. There was also a significant correlation between phonetic errors and orthographic awareness, again suggesting that letter knowledge was a core skill. This knowledge was not, however, related to the intelligibility of children’s own speech. Indeed, speech intelligibility was not related to any of the other measures that we used, and, as we have noted, it did not discriminate Good and Poor Readers.

<table>
<thead>
<tr>
<th>Child</th>
<th>Reading lag (months)</th>
<th>Phonetic errors (%)</th>
<th>Correct syllables (%)</th>
<th>Orthographic awareness</th>
<th>Speech intelligibility</th>
<th>Speech reading (words)</th>
<th>First language</th>
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<td>0</td>
<td>38.89</td>
<td>88.89</td>
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<td>4</td>
<td>41</td>
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<tr>
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<td>−5</td>
<td>11.76</td>
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<td>6</td>
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<td>4</td>
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<td>73.33</td>
<td>8</td>
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<tr>
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<td>61.29</td>
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<tr>
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<td>1</td>
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</tr>
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<td>0</td>
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<td>5</td>
<td>1</td>
<td>30</td>
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<td>2</td>
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<td>5</td>
<td>1</td>
<td>21</td>
<td>English</td>
</tr>
</tbody>
</table>

Table 7: Individual profiles of children classified as Good and Poor Readers

Note. BSL = British Sign Language.

*a*These children had a reading age that was higher than their chronological age.
underpinned the other abilities. From a theoretical perspective, however, the more likely interpretation is that speech reading ability is the core skill. This would be in line with earlier arguments about speech reading as an important mechanism by which deaf children acquire representations of phonology (Alegria et al., 1999; Campbell, 1997; Dodd, 1980). Our data suggest two lines of evidence in support of this view.

The first comes from the results of the k-means cluster analyses. These showed that, in spite of significant group differences, our measures did not always separate the two groups of readers. On phonetic errors, only 3 Good Readers fell into the higher group and 6 could not be distinguished from Poor Readers. For syllabic representation, the majority of Good Readers fell into the higher group but 2 did not; and for orthographic awareness 5 did and 4 did not. The only measure on which all Good Readers were assigned to the higher group was speech reading, showing that, whereas some Good Readers had good phonological skills and some had good orthographic skills, they were all good at speech reading.

Before accepting this conclusion it is pertinent to consider why cluster analysis also placed a majority of Poor Readers in the higher scoring group on speech reading. Table 6 shows that the standard deviation of speech reading scores was considerably lower for Good Readers (2.57) than Poor Readers (7.68) in spite of the fact that the mean score was significantly higher for the Good Readers. This unusual pattern, in which a lower mean was associated with a higher standard deviation, reflects the fact that the scores of Good Readers ranged between 35 and 43 whereas, among the Poor Readers, the highest score was 40 but the lowest was 17. In fact, only two Poor Readers had a speech reading score of 35 or more (i.e., a score that equaled those of Good Readers), so there was less overlap between the groups than the Cluster analysis might suggest. Interestingly, one of these children was the best of the Poor Readers with a reading lag of 15 months, whereas the other—the one with a speech reading score of 40—had a reading lag of 22 months. He had received a cochlear implant at 4 years and was making good use of his hearing, so it is possible that his reading ability would have improved with time to make it more commensurate with his level of speech reading.

The second line of evidence for the importance of speech reading comes from regression analyses. In order to compare the power of phonetic errors and speech reading to predict reading lag, two contrasting forced-entry regression analyses were carried out (see Table 5). When speech reading was entered as the first variable, $R^2$ change $= .47$ ($p = .002$). The addition of phonetic errors resulted in $R^2$ change $= .07$ ($p = .16$). In other words, the percentage of phonetic errors did not predict reading lag once speech reading was accounted for. When the percentage of phonetic errors was entered as the first variable, $R^2$ change $= .38$ ($p = .006$). Entering speech reading as the second variable resulted in $R^2$ change $= .16$ ($p = .040$). In other words, speech reading was still a significant predictor of reading lag even when the percentage of phonetic errors had been accounted for.

Both cluster and regression analyses of our data point to speech reading as the core skill that underpins the capacity for phonological representation. This supports arguments that have been made about orally educated deaf children (Alegria et al., 1999; Leybaert & Charlier, 1996). However, it is notable that 5 of the Good Readers in our sample had deaf parents and were native signers for whom BSL was their first language. In all these cases, however, it was reported that English was also used at home (see Table 7), supporting the argument of Marschark and Harris (1996). The other 4 children had hearing parents and, of these, 2 had very little signing, one had learned BSL at school, and the other had been exposed to BSL from birth. All 4 of these children had received cochlear implants.

In spite of their heterogeneity, all children identified as Good Readers were good speech readers. There has been considerable debate about the relationship between signing and speech reading (Mogford, 1987), and some studies have shown that the use of manual communication is associated with less proficient speech reading (Bernstein, Demorest, & Tucker, 1998). In should be noted, however, that it is not always easy to interpret findings about the relationship between signing and speech reading because decisions about the educational environment for deaf children of hearing parents are often made in the light of deaf children’s early oral abilities. In other words, signing may be introduced to children who are failing to acquire
language from oral input (Harris & Beech, 1998). The finding that children with Deaf parents, who are exposed to sign from birth and use it as their preferred language, can become good speech readers strongly suggests that competence in one modality does not preclude competence in the other. Indeed, we would suggest that, even for children who are competent signers, skill in speech reading provides an important basis for the development of a phonological code that can be used in learning to read.

It would appear, however, that Good Readers drew on their speech reading skills in different ways. Some children (notably Participants 1, 5, 7, and 8 in Table 7) appeared to be using phonological coding in a similar way to hearing children as evidenced by phonetic errors in spelling and correct representation of syllables. Other children (notably Participants 2, 4, and 9 in Table 7) appeared to be making little or no use of phonological coding because they made few or no phonetic errors; and this suggests that their reading may have relied more on coding at a whole-word level.

Within the group of Poor Readers, there was also considerable heterogeneity (see Table 7). Four of the children in this group had received a cochlear implant and 1 had a deaf mother. Three were reported as learning to sign at preschool and 3 learned to sign at primary school. The other 3 children did not sign. Intriguingly, 2 children in the group (Participants 10 and 11) had speech reading scores that were comparable to those of the Good Readers as noted above. This strongly suggests that speech reading ability does not on its own lead to reading success. Other factors, for example, good knowledge of English vocabulary, are also likely to be important. Further research is required to establish how speech reading skills interact with other abilities as deaf children learn to read. Early speech reading skills have been shown to predict developing spoken and signed language skills (Dodd et al., 1998), so one might expect there to be a complex developmental trajectory in which speech reading has both direct and indirect effects on the reading progress of deaf children.

Finally, if the conclusions of this study are correct, they throw up an intriguing question: What kind of code do deaf children derive from speech reading? As others have argued (Alegria, 1998; Alegria & Lechat, 2005; Campbell, 1997), there appears to be an abstract phonological code that is common to both listening and speech reading. Indeed, speech perception for hearing people involves the integration of information from the sounds and lip movements made by a speaker. However, in some sense the code used by deaf children is different from that used by hearing children because it reflects distinctions that are unique to speech reading. One possibility is that the code is articulatory and that what is being encoded is the movement of the articulators.

Studies of adults have shown that lip movements, together with visibility of the tongue and teeth, provide the most useful information for speech reading (Summerfield, 1979; Summerfield, McLeod, McGrath, & Brooke, 1989); so it is likely to be these aspects that are encoded. However, it is important to emphasize that in speech perception information of this kind is normally integrated with auditory information right from birth (Locke, 1993), and even where children have very little access to auditory information, they will bring these two components together. Recent work on speech reading in children who have received a cochlear implant has shown that implanted children were better at speech reading when they were presented with both visual information (i.e., tongue and lip movements) and sound than when they were presented with only one modality (Bergeson, Pisoni, & Davis, 2005). The authors emphasize the “coupling between auditory and visual sensory systems and the potential for unity and convergence . . . between these two different sensory systems” (p. 161).

In this study, there was no difference in the unaided hearing loss of the Good and Poor Readers. However, as we did not have sufficient information about aided losses, we were not able to compare these in the two groups. It is certainly possible that the Good Readers may have been able to make better use of their aided hearing and that this, in conjunction with their speech reading ability, was allowing them access to better phonological coding than the Poor Readers. It is interesting to note, however, that in the Bergeson et al. (2005) study, it was performance in speech reading where there was no sound that best predicted speech and language development after implant. This suggests, that for children who are profoundly deaf, the visual component of speech reading is an especially important skill.
Notes

1. In spite of evidence for the utility of CS for deaf children learning French, the evidence for children learning English is less convincing. Alegria and Lechat (2005) note some differences between French and English, especially in the higher incidence of diphthongs in English, that may make CS less useful for English.

2. Unequal variances were assumed for this comparison.

3. In view of the number of comparisons that were made, it was decided to set \( p = .01 \) as the criterion for significance, using a one-tailed test.

References


Received October 6, 2005; revisions received December 1, 2005; accepted December 11, 2005.