Reading and Dyslexia in Deaf Children

Dr Rosalind Herman

Professor Penny Roy

Dr Fiona Kyle

City, University of London

Q: What measures can be used to identify dyslexia in deaf children? How does reading attainment compare between deaf children with different communication preferences? How does reading in deaf and hearing dyslexic children compare? Are measures equally effective for deaf and hearing dyslexic children? Is there a 'deaf dyslexic' profile? What key factors are associated with good and poor reading in oral and signing deaf children?

Summary

Literacy difficulties are more widespread among deaf* children than hearing children but reasons for their problems differ. Hearing children are likely to be described as dyslexic and once diagnosed, may benefit from specialist support. However, for deaf children, their hearing difficulties are seen as primary. In this Briefing Paper, we report findings from a two-phase research study on deaf children's reading, funded by the Nuffield Foundation. Phase 1 focused on a large sample of 82 same-age deaf children aged 10-11 years who communicated using spoken language (oral deaf children) and Phase 2, on a sample of 59 same-age deaf children who used sign language to communicate (signing deaf children).

Our analysis identified that literacy scores in both deaf groups were lower than expected for their age, and lower in the signing group compared to the oral group. An exception was the small group of signing children with two deaf parents, who achieved reading levels comparable to oral deaf children. Overall, 48% of the oral group and 82% of the signing children were reading below age level. Scores for spelling were better than reading but in both groups, many children had below average scores. In both groups, literacy outcomes were associated with phonological skills and language. Profiles of poor readers in each group were similar, and displayed low scores on English expressive vocabulary and phonological measures.

Using our hearing dyslexic participants as a reference group, we were able to identify dyslexia-sensitive measures that were effective in differentiating poor readers in the oral deaf sample since children in the oral deaf group were able to access the full range of measures developed for hearing children. Identification of a dyslexic profile among the signing participants was more complex as different phonological measures were used that did not rely on speech perception or production, and also because of their very low scores on many of the measures: the percentage of poor readers with scores falling below -2 SDs was nearly four times higher in the signing group compared with the oral deaf group, accounting for nearly a quarter of the signing sample.

Our findings highlight the scale of reading difficulties in deaf children. Regardless of communication approach, all deaf poor readers are in urgent need of specialist intervention to address the deficits underlying poor literacy. Interventions known to be effective with hearing children with reading difficulties should also be used with deaf poor readers. In addition, deaf children require support to develop their language skills. Our findings also suggest that spelling, a relative strength in deaf children, may offer a useful route to improving literacy in this group.

**The terms 'deaf' and 'hearing impaired' are often used with this group. We use the term 'deaf' here to refer to individuals with a prelingual severe-profound degree of hearing loss, i.e. one that is present at or shortly after birth.*

Reading and dyslexia

Reading involves two separate skills:

- *Decoding skills* involve translating the letters that make up written words into the sounds of spoken language, e.g. c-a-t. Decoding skills are important when learning to read and also when reading unfamiliar words or nonsense words (i.e. non-words, e.g. yutnip). Decoding skills are reliant upon an established speech sound (phonological) system.
- *Comprehension skills* are needed to understand decoded words. Comprehension is based on a well-developed language system.

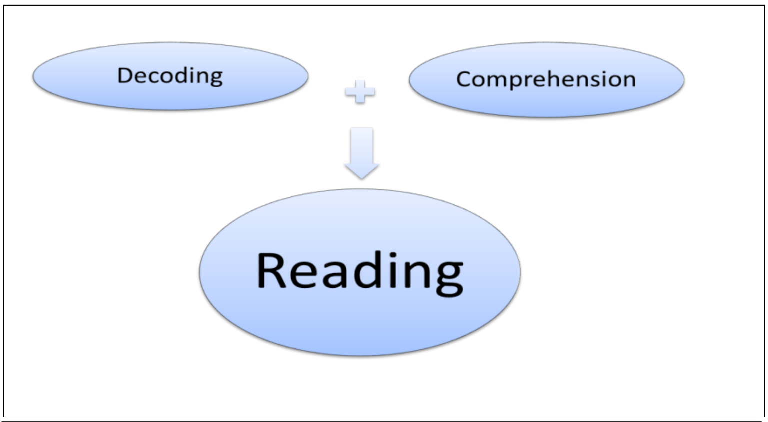

Figure 1. Skills involved in reading (Gough & Tunmer, 1986)

Children and adults with dyslexia typically have specific difficulties with the first of these areas, and there is sometimes a genetic component to dyslexia. More boys than girls are affected, and social factors may also be involved.

In addition to problems with decoding written words, dyslexia is associated with difficulties remembering certain types of information (e.g. telephone numbers), problems moving sounds around in words (such as exchanging the initial sounds of words, e.g. 'dog' with a 'l' becomes 'log') and accessing phonology at speed (e.g. naming pictures or digits as fast as possible). Together, these are known as phonological deficits. When testing a child for dyslexia it is common to use assessments that measure phonological skills and to look for discrepancies in these domains in comparison with other areas of strength. *(Note: In line with recent thinking, our model of dyslexia is phonological).*

Figure 2 below illustrates theoretical profiles of hearing readers with different strengths and weaknesses in decoding and language skills, although in practice children rarely fit these exactly. Children with dyslexia are typically poor readers (PR) because of weak decoding skills. This is in contrast with the profile of children who have adequate decoding skills but poor language skills. We will call this group 'poor language' (PL, see Figure 2). In addition to these two groups are children with decoding and language skills that are average for their age - we have called these 'average readers' - and children with both poor decoding and poor language skills, here termed poor readers plus poor language (PR+PL).

The UK government-commissioned Rose Report 'Identifying and Teaching Children and Young People with Dyslexia and Literacy Difficulties' (2009) noted poor literacy to be associated with educational failure, emotional and behavioural problems in the school years, and reduced earning potential, increased risk of unemployment and social exclusion in adulthood. For these reasons, there has been considerable interest in understanding the underlying causes of poor literacy, improving identification and developing effective interventions.

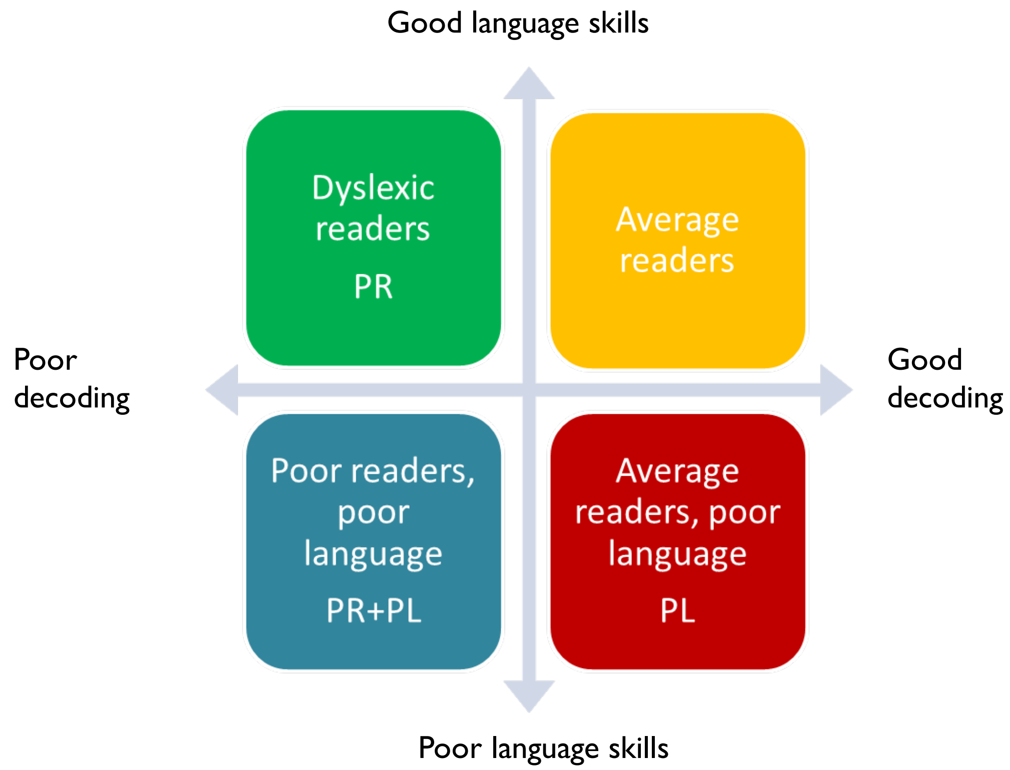

Figure 2. Impact of decoding and language skills on reading (adapted from Bishop & Snowling, 2004)

To date, this research has focused on dyslexia among children and adults with normal hearing. Yet, given the genetic basis of dyslexia in the hearing population, it is likely that a proportion of deaf readers are dyslexic and indeed teachers often suspect this is the case. One challenge is how to differentiate deaf children who are poor readers due to limited exposure to key pre-reading experiences from those who are dyslexic. The challenge is compounded by the lack of information about typical reading profiles among deaf children and adults. How do you decide if an individual child's profile of skills is uneven or discrepant if you do not know the typical profile of skills for any one age group?

The development of standardised assessments has played a key role in the recognition of dyslexia in recent years, as well as in the identification of other groups of poor readers. Standardised assessments enable us to compare an individual child's test performance with others of the same age and also inform the design of interventions for hearing children with reading difficulties. However, there are no comparable tests in the UK for deaf children and no normative data. The research described in this Briefing Paper is a first step towards redressing this balance.

Childhood deafness and reading

Recent estimates suggest that there are almost 49,000 children with a permanent hearing loss in the UK (CRIDE 2015), and over 90% come from families with no experience of deafness. Approximately a quarter of affected children have a severe-profound degree of loss that significantly impacts their access to spoken language. Of these, the vast majority use spoken language to communicate. However, a significant proportion (10%) use sign language, either on its own or alongside another language.

Because of their hearing loss, deaf children have difficulty hearing the speech sounds that make up spoken language (i.e. phonology), upon which written language is based. In addition, deaf children often struggle to understand language that is not specifically addressed to them and therefore cannot benefit from incidental learning. As a consequence of their impoverished input, deaf children can have speech that is difficult to understand and levels of language and literacy development markedly below their hearing classmates, despite a normal range of intelligence. A variety of factors, such as when deafness was identified, the degree of deafness, the benefit obtained from hearing aids or cochlear implants, the preferred form of communication, etc., contribute to further differences among deaf children.

Despite these factors, research suggests that most deaf children follow essentially the same route to reading as hearing children. This is especially true of oral deaf children, i.e. those who predominately use spoken rather than sign language to communicate. Phonological skills play a central role in reading for both groups although, unlike hearing children, many deaf children develop their phonological skills by combining information obtained through listening with hearing aids and cochlear implants with information obtained from observable lip-patterns, i.e. speechreading.

Most research on deaf children's reading includes samples with mixed communication modes and there are relatively few studies that look exclusively, or separately, at deaf children who sign. However, signing deaf children face completely different challenges when learning to read. There is no written form of sign language, therefore signers must not only learn a new orthographical code in order to read, they must also acquire a different language. Signing deaf children also present different challenges for assessment, since many are unable to respond using spoken language. Moreover, within the available research, there are contradictory views on the significance of phonological skills for deaf children who sign. Whether or not phonological skills play a role is important for two reasons: firstly, in helping our understanding of how best to teach signing deaf children to read; and secondly, in determining whether some signing children may have dyslexia, which is typically identified through performance on phonological tasks.

In recent years, deaf children in the UK and elsewhere have benefitted from earlier diagnosis through newborn hearing screening and better amplification through more widespread use of cochlear implants and digital hearing aids at younger ages. As a result, many deaf children now have improved access to spoken language and more intelligible speech. Higher levels of achievement have been reported at the early stages of learning to read and among certain groups of deaf children, e.g. those with cochlear implants and those who communicate orally. However, significant gaps in reading levels between deaf and hearing children are still reported for a large proportion of deaf children, gaps that widen as children get older.

Research study

A research study was set up to investigate reading and dyslexia in deaf children. Phase 1 focused exclusively on oral deaf children, since they most closely follow the route to reading taken by hearing children. Following this, Phase 2 was initiated to investigate reading and dyslexia in signing deaf children. For both phases, the research team comprised Dr Rosalind Herman, Professor Penny Roy and Dr Fiona Kyle from City, University of London. In this Briefing Paper, we summarise the analyses of our data across the two phases and consider the implications for improving reading attainment in deaf children.

The main aims of the research were:

1. To recruit representative samples of oral and signing deaf children at the end of their primary education.
2. To investigate the suitability of literacy and dyslexia-sensitive measures developed for hearing children for oral and signing deaf children, and to replace any found to be inappropriate with equivalent measures.
3. To compare reading attainment in deaf children with different communication preferences.
4. To explore profiles of average and poor deaf readers according to communication preference.
5. To compare reading attainment in deaf and hearing dyslexic children.
6. To compare profiles of average and poor readers across deaf and hearing groups.
7. To explore whether measures were equally effective for deaf and hearing groups.
8. To determine whether there is a 'deaf dyslexic' profile.
9. To identify key predictors of literacy skills in deaf children.

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A representative sample of deaf children

Deaf children aged 10-11 years in Year 6, their last year of primary school, were identified as the target group. By this age, children would be expected to have established reading skills and if not, teachers urgently need to know since transfer to secondary education is imminent. Although a diagnosis of dyslexia is often sought at a younger age among hearing children, this is less feasible in deaf children at the same age as so many have a delayed start to reading and progress more slowly.

Phase 1: Oral deaf participants

We recruited 82 children (mean age 11 years) with a severe-profound level of deafness who used spoken language to communicate. Participants were recruited from all parts of the UK across the two years of this phase of the study. All were reported to be deaf from or shortly after birth, i.e. they were prelingually deaf. All children who could attempt the test battery, which included measures used to diagnose dyslexia in hearing children, were encouraged to do so. Three children were excluded: two because of poor levels of speech intelligibility and one child who could not comply with the literacy measures. This left a final sample size of 79 children, which represents approximately 2% of oral deaf children in the UK within this age group and is larger than samples included in other studies. Moreover, the sample is equivalent to a sample of approximately 6,500 hearing children in year 6 in England (DfE, 2016).

There were approximately equal numbers of girls and boys and children came from a range of backgrounds in terms of parental education and ethnicity. *57 (*75%) attended resource units for deaf children within mainstream schools; 18 (24%) were in mainstream schools unsupported, and one child (1%) attended a school for deaf children. All children had attended an English speaking school since Year 1 and used English as their dominant language. Additional health difficulties were reported for seven children, and one further child had a language disorder. A large majority had hearing parents; only one child had two deaf parents and two children each had one deaf parent. 48 *(*61%) used one or more cochlear implants (one child used one digital aid and one cochlear implant); the remainder used digital hearing aids. Speech intelligibility ratings varied within the group: 76 (96%) had at least average intelligibility.

Phase 2: Signing deaf participants

Fifty-nine children were recruited from all parts of the UK across the two years of the second phase of the study and tested. Nine were later excluded because they were unable to complete all measures either due to non-attendance (5), because their level of deafness did not meet our criteria (3) or because they were significantly younger than the rest of the sample (1). This left a final dataset of 50 participants (mean age 10 years 11 months) with prelingual severe-profound deafness. There were 20 girls and children were from a range of ethnic backgrounds and levels of parental education. This sample size represents approximately 8% of signing deaf children in the UK within this age range. It is therefore larger than samples included in other studies.

Twenty-seven (54%) children were based in resource units for deaf children within mainstream schools, 17 (34%) attended special schools for deaf children, and six (12%) attended mainstream schools. All children had been in an English and/or British Sign Language (BSL) speaking school since Year 1; however, the communication approach used in schools varied. Some schools reported using BSL and spoken English; others described a range of communication approaches used according to individual need, including spoken English, BSL, Sign Supported English (SSE, the use of BSL signs to accompany spoken language), Total Communication (the use of spoken English, BSL and SSE), and in some cases, Cued Speech (a system of manual cues to facilitate speechreading). The children themselves reported used signing to varying degrees, either preferring BSL as their dominant language, or using it equally with English, or using BSL mainly to access the curriculum. For some participants, signing had been used more when they were younger and was used less frequently at time of testing.

Fourteen (28%) used cochlear implants, 31 (62%) used digital hearing aids and four children (8%) had no hearing amplification device. Five children had one deaf parent, nine had two deaf parents and the remaining 36 had hearing parents. Eleven children (22%) were reported to have additional health difficulties; of these, nine of these were associated with language/communication difficulties (e.g. autistic spectrum disorder, dyspraxia). Speech intelligibility ratings varied widely within the group: 36 (72%) had poor or very poor speech intelligibility and preferred to respond exclusively in BSL, therefore the phonological tasks that did not require spoken responses were used with all participants. This meant that different phonological tasks were used with each deaf group. In addition, as measurement of accuracy in passage reading task proved to be unreliable because of poor speech intelligibility, the reading accuracy measure was not used in further analyses.

For both groups, background information was obtained from parents on family history of hearing, language or reading difficulties and family reading habits, and from teachers on school communication approaches.

Hearing children with dyslexia

Twenty hearing children with identified dyslexia completed the same test battery to act as a reference group for comparison principally with the oral deaf participants. Recruitment was extremely challenging and as a result, compared to the deaf participants, the hearing dyslexic sample was less representative and younger. Children attended either mainstream schools or specialist dyslexic units and schools in London, Yorkshire and the East and South-East of England only and all had received or were continuing to receive interventions for their dyslexia. There was a similar range of social backgrounds as in the deaf group, but a disproportionate number of fathers were educated to degree level or above. The age range was wide (8-11 years), with a mean age of 10 years 1 month. There were approximately equal numbers of girls and boys.

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Measures used to identify dyslexia in deaf children

Tests selected were known to measure skills related to reading and dyslexia in hearing children. Additional tests targeted skills known to be important to reading in deaf children only. The test battery covered the following skills (see Appendix for full details):

- Nonverbal skills
- Literacy skills (letter-sound knowledge, single word & non-word reading, reading comprehension, spelling)
- Phonological skills (see Table 1)
- Naming speed (pictures and digits)
- Fluency (semantic and rhyme) skills
- Language skills (expressive vocabulary; BSL skills)
- Speech intelligibility[1]
- Speechreading skills[2]
- Sequential organisation skills

For signing participants, the same test was used to elicit BSL and English expressive vocabulary, although standard scores were generated for English only. Two additional language measures were used for this group: standardised tests of BSL receptive and production skills (see Appendix).

A range of phonological skills was assessed (see Table 1). Some of the tests from Phase 1 were also used in Phase 2. However, as many signing deaf children had limited speech intelligibility and/or difficulties with speech perception, alternative tests were included in place of those requiring spoken responses, or where test administration relied on spoken presentation. Although every effort was made to identify alternative measures that tested similar skills, there were some areas for which no alternative measure was available.

Phase 1: Oral deaf participants

Children were tested in school by a researcher skilled in communicating with deaf children. In all cases, test instructions were delivered in spoken English. However, sign support or British Sign Language was used according to teachers' recommendations to help children understand what was required when introducing tests. For some tests, additional practice items were included. Following these adjustments to the test procedure, all children were able to attempt the full test battery. All oral deaf children responded using spoken English.

[1,2]*These measures assess skills known to be significant for deaf children's reading.*

As many deaf children have poor speech intelligibility, responses were filmed to check for scoring accuracy. In addition, 10% of children's responses were scored separately by an independent person to check scoring reliability. Scoring reliability was high for all measures with the exception of accuracy in reading aloud. For this measure, some deaf children's speech difficulties made it difficult to reach agreement between independent scorers. Therefore, this measure was not included in subsequent analyses.

Phase 2: Signing deaf participants

Children were tested in school by a researcher skilled in communicating with deaf children using BSL. Instructions were delivered in BSL or SSE, according to teachers' recommendations, to ensure children understood what was required. As previously, for some tests, additional practice items were included. Children responded using BSL or SSE, with a minority responding in spoken English.

Phonological skill tested	**Test used with oral deaf and hearing dyslexic participants in Phase 1**	**Additional/alternative test used with signing participants in Phase 2**
Generating words that rhyme	Rhyme fluency (English)	Rhyme fluency (BSL)
Matching words that rhyme	Rhyme awareness	Rhyme awareness[3]
Generating/matching words that start with the same sound	Alliteration fluency	Initial phoneme identification[4]
Recall of digits forwards and backwards	Digit span (English)	Digit span (BSL)
Manipulating sounds within words[5]	Spoonerisms Phoneme deletion	n/a
Naming speed for pictures and digits	Naming speed for pictures and digits (English)	Naming speed for pictures and digits (BSL)
Non-word reading/matching	Non-word reading	Non-word matching[4]
Nonsense sign repetition[6]	n/a	Non-sign repetition

[3]Alternative measure similar to the original that included pictures rather than spoken presentation.[4]Alternative measure used in previous research with deaf children. [5]Tests known to be discriminating in hearing children with dyslexia, however no equivalent measure suitable for signing deaf children was identified. [6]Measure used to investigate phonological skills in sign language.

Table 1. Phonological tests used with oral and signing deaf children

Again, all measures requiring spoken or signed responses were video recorded. Measures that had not previously been checked for rater-reliability in Phase 1 were checked for scoring accuracy and inter-rater reliability. Scoring reliability was found to be high for all new measures with the exception of BSL expressive vocabulary. Following an exploration of issues underlying the lack of reliability, a third rater rescored all data, after which, a satisfactory level of inter-rater reliability was achieved.

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Reading attainment in deaf children with different communication preferences

Unlike the findings of some other studies, we found no differences between deaf children using cochlear implants and those using digital hearing aids on any of our measures and in either of our deaf groups. In the signing group, this included a small number of children using no form of amplification. For subsequent analyses, a single combined group of implant and hearing aid users was therefore used for each deaf group.

Children in both deaf groups achieved literacy scores significantly below (<-1SD) the expected level based on hearing test norms, with scores in the signing group below those of the oral group. For both groups, spelling was better than reading, but was still poor.

Language scores on the expressive vocabulary measure were particularly low for all deaf children (<-2SD), with scores in the signing group lower than those of the oral group. Comparing the signing deaf children's expressive vocabulary in English and BSL using raw scores, English was notably weaker than BSL vocabulary. The signing group's scores on a test of BSL receptive language skills were within the expected range.

Letter-sound knowledge was weak in both groups and scores on many of the phonological tasks were also low. For the non-standardised phonological measures used with the signing group, we compared the deaf children's scores with data collected from typically developing hearing children at 6, 7 and 8 years of age. The signing deaf children's scores most closely matched those of the youngest hearing children.

Both oral and signing deaf children achieved similar scores that were within the expected range on nonverbal, naming speed for pictures and recall of digits forwards and backwards tasks. Scores for semantic fluency and speechreading were also within the normal range, with oral deaf children achieving higher scores than the signing group on both. Recall of digits forwards scores were much lower in both groups.

Of the remaining measures, i.e. speech intelligibility, rhyme fluency (the only phonological task common to both groups) and naming speed for digits (see Figures 1 and 2), the oral group outperformed the signing group.

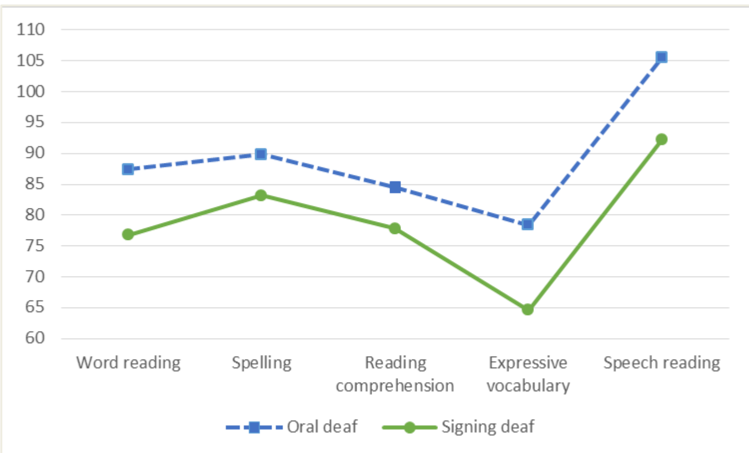

Figure 1. Mean standard scores on literacy, language and speechreading measures common to both oral and signing deaf groups

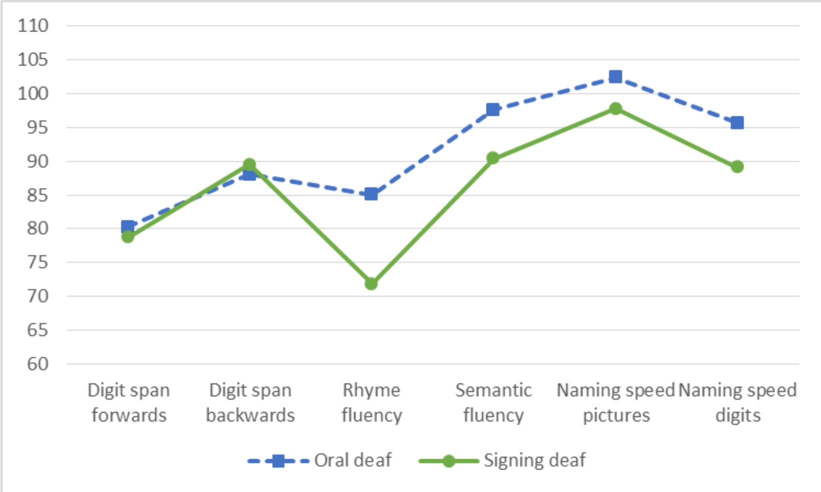

Figure 2. Mean scores on phonological measures common to both oral and signing deaf groups

Within the signing group, differences were apparent for children with two deaf parents versus the rest of the group. Scores for this subgroup were significantly higher and very similar to children in the oral sample. However, for children with one deaf parent, scores were poorer and more closely aligned to those of deaf children with hearing parents. This finding suggests that early and good quality exposure to signing, as found in signing deaf families, can support literacy development. However, where signing exposure is later or more variable in quality, literacy attainment is likely to be lower.

We explored the associations between our measures and a similar pattern emerged for both oral and signing deaf groups. Expressive vocabulary was strongly correlated with reading, more so for English than BSL vocabulary in the signing group. Phonological measures were correlated with reading across both groups, but there were exceptions. For example, naming speed for digits was not discriminating in the signing group. In the signing group, non-sign repetition was associated with BSL language skills, but not with reading. Like hearing children, these findings indicate the importance of speech-based phonological skills for reading in deaf children, regardless of communication preference.

How do deaf and hearing dyslexic children compare?

In common with the deaf groups, hearing children with dyslexia found many of the literacy tasks challenging, although unlike the deaf participants, spelling was more difficult for some hearing dyslexic children than reading.

We saw above that deaf children were reading below the expected level. The hearing dyslexic group were also below the test norms for their age. In terms of reading age equivalents, the dyslexic group were one year below on single word reading, the oral deaf group were two years below and the signing deaf group were three years below. However, because the hearing dyslexic children were younger than the deaf children, the oral deaf and hearing dyslexic children turned out to be matched for reading ability. The oral deaf and hearing dyslexic groups were both 18 months below on the spelling task; the signing deaf group mean was two years below. More oral deaf children than hearing children with dyslexia had below average scores on non-word reading, but the difference was less marked than for single word reading. *(Note: the signing group did not complete the non-word reading task).*

Whereas the dyslexic children's scores for expressive vocabulary and reading comprehension were as expected for their age, 70% of the oral group and 88% of the signing children had below average scores for vocabulary, and 60% of the oral group and 84% of the signing children were below average for reading comprehension. Figure 3 shows the percentage of test scores that were below average in the oral deaf and hearing dyslexic groups.

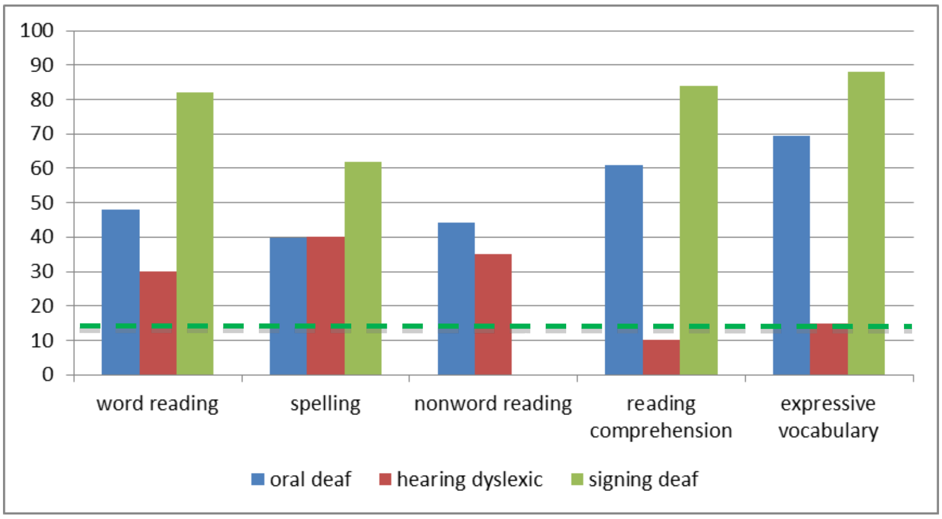

Figure 3. Percentage of below average literacy and language scores for oral and signing deaf children and hearing dyslexic children
(Note: dashed line indicates expected levels)

Average, poor and extremely poor readers in each group

Based on test scores for single word reading, deaf and hearing dyslexic children were divided into average (>=-1SD), poor (<-1SD) and extremely poor readers (<-2SD). No children were reading above their age level. Figure 4 shows the percentage of children in each category according to group.

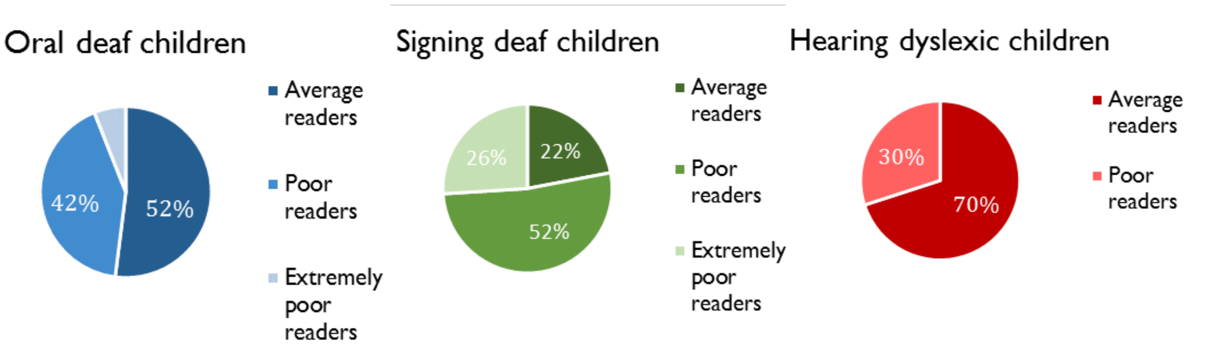

Figure 4. Average, poor and extremely poor readers in the deaf and hearing dyslexic groups

There were many more average readers in the oral deaf than in the signing deaf group. Over half of the oral deaf group (52%) were reading at age level, whereas this was only true of less than a fifth (18%) of the signing deaf group. In comparison, 70% of the hearing dyslexic group were reading at age level.

Among the poor readers in each deaf group, a number of children (6% in the oral group and 24% in the signing group) achieved extremely low scores that were less than two standard deviations below the mean (<-2SD) and were extremely poor readers. No equivalent group was found among the hearing dyslexic group.

Profiles of average and poor readers

Using single word reading as the measure of decoding skill and English expressive vocabulary as the measure of language (vocabulary scores were highly related to reading comprehension scores), Figure 5 presents the distribution of deaf and hearing dyslexic children according to these same profiles. (*Note: We acknowledge the limitation of using this type of profiling in view of the continuous nature of children's scores*).

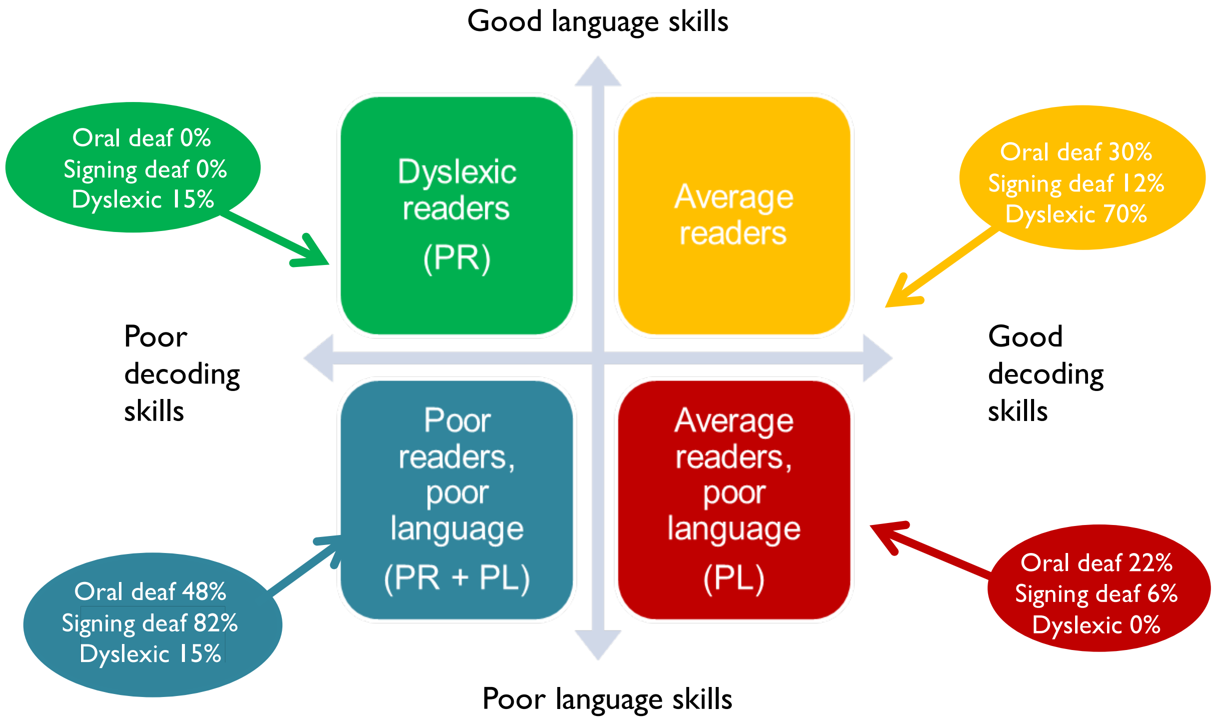

Figure 5. Distribution of average and poor deaf or dyslexic readers according to decoding and language skills

From this, we can see that the majority of the dyslexic children in our reference group were average readers with decoding and language skills within the average range. These can be considered as compensated dyslexics as a result of receiving specific interventions. None of the dyslexic group had poor language only (PL). Half of the dyslexic poor readers (15%) fit the theoretically based dyslexic profile of poor readers (PR) with weak decoding alongside average language skills. The other 15% had weak decoding in addition to weak language skills, i.e. poor reading and poor language (PR+PL). This varying profile fits in with the view of dyslexia as being along a continuum of reading difficulty.

In contrast to the dyslexic children, a substantial proportion of oral deaf average readers and a small number of signing deaf average readers were found to have poor language (PL).

Although currently reading at an average level for single words, these children could be considered at risk of future reading problems because of their language difficulties, as are the PR+PL children. Only 30% of oral and 12% of signing deaf children were reading at age level with appropriate language skills.

No deaf poor reader fit the classic dyslexic profile of weak phonological skills and average language. Nevertheless, we will see later that other measures identified different profiles of phonological deficits amongst the deaf poor readers.

Within the large number of oral (48%) and signing (82%) deaf poor readers, all showed weak decoding and language skills (PR+PL). *(Note: Taking non-word reading as a measure of decoding skills for the oral deaf and hearing dyslexic groups rather than single word reading had very little impact on the distribution of average and poor readers across profiles in either group).*

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Were measures equally effective for deaf and hearing dyslexic children?

Many of the tests identified average and poor readers in both deaf and hearing dyslexic groups. However, a few tasks were only effective in one or other group, e.g. tasks involving rhyme were particularly challenging to deaf children. In all cases, these test scores were uniquely associated with vocabulary in the deaf samples. In contrast, the measure of short-term verbal memory (recall of digits forward), known to be affected in dyslexia, was sensitive in the hearing dyslexic and signing deaf groups, but interestingly not in the oral deaf group.

Additionally, over half of the hearing dyslexic children (compared with 8% of the oral deaf and 26% signing deaf groups) found the speechreading task difficult, but there was no relation between speechreading skills and literacy performance for the dyslexic group.

Further analysis revealed the main difference between the deaf and hearing dyslexic groups to be the key role of vocabulary for reading and spelling. Even when reading entirely unfamiliar words (non-words), vocabulary was a significant predictor in the oral deaf group. Speech intelligibility measures in oral and signing participants were related to phonological and reading outcomes.

The type of spelling errors the children made was also informative (see Figure 8). We found that children varied in the proportion of phonetic errors they made (e.g. lepered for 'leopard'). Almost all the hearing dyslexic group made mainly phonetic errors, indicating they were using a phonological route to reading and spelling. Roughly equal proportions of the oral deaf sample made mainly phonetic errors, mainly non-phonetic errors, or a mixed pattern of phonetic and non-phonetic errors. In the signing group, a different pattern was observed, with a majority making mainly non-phonetic errors.

For both deaf groups, phonetic or mixed errors were associated with better reading and spelling. Mainly non-phonetic errors (e.g. cuircle for 'circle') were found almost exclusively among the poorest spellers and readers in the deaf groups. For these children, there is little evidence that they are using a phonological route to literacy. However, a small group of oral deaf children who were poor readers made mainly phonetic errors, like the hearing dyslexic children.

Sequencing the months of the year was challenging for some poor deaf readers and furthermore, discriminated between the poor and extremely poor readers in both deaf groups.

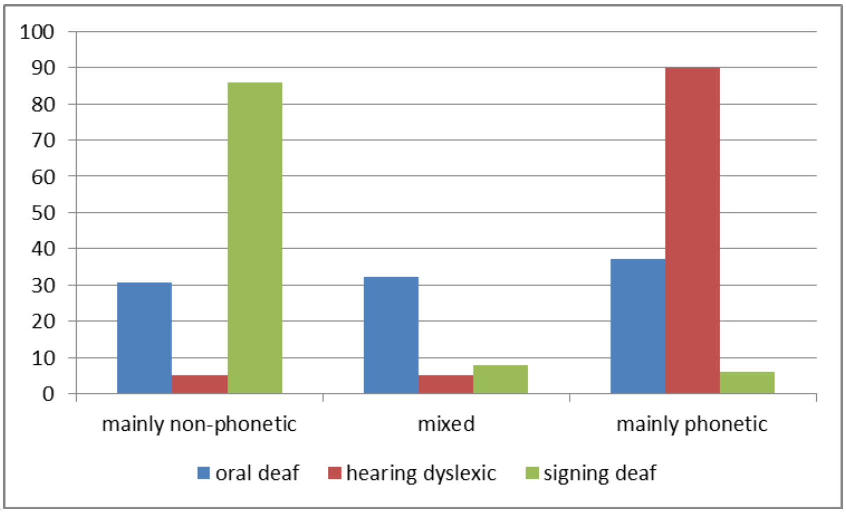

Figure 8. Percentage spelling errors in deaf and hearing dyslexic children

Some comparisons were only possible between the oral deaf and hearing dyslexic groups because they were able to complete the same measures. In these two groups, the profile of phonological deficits associated with poor literacy at this age was strikingly similar; in line with previous evidence, tasks involving the manipulation of sounds (e.g. phoneme deletion, spoonerisms) were particularly significant for reading, and naming speed for digits was significant for spelling.

A 'deaf dyslexic' profile?

Our oral deaf participants completed all of the test measures used to diagnose dyslexia in hearing children, yet none presented with the typical dyslexic profile of good language and poor decoding. Nonetheless, we did identify some cases in this group with profiles similar to those of hearing children with dyslexia, based on a series of risk factors. In order to make a decision about dyslexia using the model of dyslexia we have followed, we need to be sure that children are using a phonological route. In cases where children's scores are at floor (the extremely poor readers), this is not possible. For such children, responses to a phonological intervention would be informative.

Close inspection of children's profiles of performance across a number of measures was helpful in identifying strengths and weaknesses. We noted previously that oral deaf children's performance on the naming speed for digits task did not differ from that of the hearing norms. This makes it a potentially useful measure to identify deaf children with specific reading difficulties. In addition, some oral deaf children with low phonemic awareness scores had higher scores on spoonerisms than the phoneme deletion task, and showed spelling errors indicative of their use of the phonological route to reading. Furthermore, whilst *all* poor readers in the hearing dyslexic group had very low non-word reading scores (<-1.5SD below the mean), this was not the case amongst the poor readers in the oral deaf group. Just over two thirds of these readers had very low non-word reading scores, a sixth had borderline scores (≥-1.5SD <-1SD), and a sixth had non-word reading scores in the average range (≥ -1SD).

Using non-word reading, spelling error strategy, phonological skills and naming speed for digits measures, we were able to identify distinct profiles among the poor readers in the oral deaf group. The most clear cut cases were those children who showed deficits on all of these measures. However, as we found with our hearing sample, some children with deficits in two or more of these areas, will be diagnosed with dyslexia.

Figure 9 presents the risk factors for dyslexia using the four measures. Risk of dyslexia in oral deaf poor readers increases among children with low non-word reading scores, who make phonetic spelling errors and have deficits in either phonological skills or naming speed for digits or both: the greater the number of risk factors, the higher the likelihood of dyslexia.

Measure	**Risk present yes/no**
Non-word reading: low	
Spelling strategy: phonetic/mixed pattern of errors	
Spoonerisms and/or phoneme deletion: low (vs both scores at floor)	
Naming speed for digits: low	

Figure 9. Risk factors for dyslexia among deaf poor readers

A cut-off of <-1.5SD on the non-word reading test was taken as all the poor readers in the hearing dyslexic group achieved scores lower than this. Of the poor readers in the hearing dyslexic group, 33% had 4, 33% had 3 and 33% had 2 risk factors. Of the poor readers in the oral deaf group, 11% had 4, 18% had 3, 47% had 2, 21% had 1 and 3% had no risk factors. A number of the oral deaf poor readers with few risk factors showed little or no evidence of using the phonological route to reading, a pattern not shared by the poor readers in the hearing dyslexic group.

As different measures were used with the signing group, the same risk factors cannot be applied. As shown above, exceptionally few signing deaf children used a phonetic spelling strategy. Only 9 (18%) attempted the non-word reading test, a key risk factor and measure of decoding. Furthermore, naming speed for digits test scores did not show the same relationship with literacy measures as found in the other groups. For the large proportion of children in the signing group with extremely poor reading and the lowest test scores, the only way to determine the presence of dyslexia would be their response to a phonologically based intervention.

The role of vocabulary in deaf children's reading

Some of the average readers in our deaf samples had average language skills. However, some of the average readers and all poor readers had weak expressive vocabulary skills. Our study, in line with other studies, has shown the key role of vocabulary in deaf children's literacy skills. Although expressive vocabulary was the only English language measure used in this study, it is acknowledged that vocabulary and wider English language skills are associated in reading English. This is equally true for signing deaf children, for whom English is a second language.

Many of the signing children in our sample demonstrated good BSL language skills, including good expressive vocabulary in BSL, but this was less strongly associated with reading than English vocabulary.

We noted at the outset that learning to read involves two skills: decoding and language. Our research shows these skills to be particularly closely related in 10-11 year-old deaf children. Other research based on hearing children has shown that this relationship is there from the early stages of learning to read. The evidence from our data and others suggests that the very limited exposure to early language experienced by most deaf children impacts on vocabulary development, speech perception and speech production, with consequences for the development of phonological representations and word learning efficiency. This is similar to the consequences of impoverished language input that has been observed in children from socioeconomically disadvantaged backgrounds. The interdependency of these early skills has longer-term implications, not only for language, but also for the development of reading skills (see Figure 10).

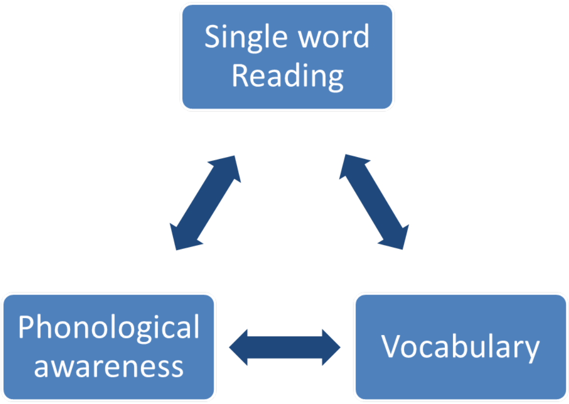

Figure 10. Relation between reading, phonological awareness and vocabulary

Although use of cochlear implants was not related to different outcomes from those of children with hearing aids in either deaf group, there was a small negative correlation between age of implant and literacy outcomes in the oral deaf group only. Our findings show very early use of cochlear implants to be protective of literacy skills in oral deaf children. None of the 13% of oral deaf children who had been implanted at 18 months of younger (most were less than a year) had below average scores on literacy, although nor were they among the best readers in their group. The child with the lowest performance in this group had social factors that may have compromised their vocabulary and reading.

Conclusions and implications of findings

This research has established that it is possible to use reading and dyslexia-sensitive tests developed for hearing children successfully with oral deaf children. Many of these tests can also be used with signing deaf children, however careful consideration must be given before using available phonological measures with this group and alternative measures are also required. Our findings have implications for the skills needed by professionals who work with deaf children, in terms of test selection and administration, in order to ensure that testing is effective in achieving valid scores.

Our analyses showed half of oral deaf children and four fifths of signing deaf children to be reading below the expected level for their age. All poor deaf readers displayed weak language difficulties and inadequate phonological skills, with children in the signing deaf group achieving lower test scores on all literacy and phonological measures. Furthermore, some children who may be considered average readers are at risk of developing reading comprehension problems because of poor language.

Using the 1996 BAS II norms that were available during the first phase of data collection, our study found that just over half of the oral deaf children tested were reading at an average level for their age. With the publication of new norms for the BAS 3 in 2011 came the opportunity to reanalyse our data. From this new analysis, only 29% of the oral deaf group and 6% of the signing deaf group emerged as average readers, indicating a much larger proportion to be poor readers than previously, and the number of poor readers among the hearing dyslexic group also increased. This finding underscores the lack of progress in reading made by deaf children and hearing children who are poor readers in comparison with their classmates in recent years. For deaf children, this is cause for concern, in view of advances in earlier identification of deafness and developments in hearing technology. Even children in our study with cochlear implants displayed a range of reading performance, suggesting that provision of cochlear implants can lead to intelligible speech for some, but this does not guarantee good reading.

In both deaf groups, language emerged as a key predictor of literacy. However, among average readers, phonological skills varied between the groups. Whereas all oral deaf average readers also had average phonological skills, some profiles of the very small group of signing deaf average readers showed variable levels of phonological skill: all demonstrated good speechreading, but only some demonstrated good skills as measured by other phonological tasks.

We found some oral deaf children displayed a dyslexic profile, but this was more difficult to determine in the signing group as we used different measures and we also found different relationships between some of the measures. Of the large numbers of children we identified with significant reading difficulties, some exhibited phonological skills that were at such a basic level, it is impossible to tell whether or not they are dyslexic. Research has suggested that response to intervention can be one way to confirm a diagnosis of dyslexia. It is our view that interventions designed for hearing children with reading difficulties may also benefit oral deaf children, and could be modified for use with signing deaf children. For very poor deaf readers, their response to intervention may be revealing about the nature of their reading difficulties. Identifying the severity and nature of deaf children's reading difficulties provides an important step towards assessing individual needs and monitoring progress in response to interventions.

In 2009, the Rose Report stated that every child should have the opportunity to succeed in reading to ensure success in education and in life. The report further states the need for quality intervention for all children with reading difficulties. The report does not include deaf children at any stage and this is cause for concern. We have identified a large proportion of deaf children with reading difficulties at least as severe as the problems faced by hearing children with dyslexia; indeed, some of our deaf sample present with difficulties that are more severe, with many displaying poor letter-sound knowledge, one of the more basic prerequisites for reading. And yet, unlike for hearing children with dyslexia, there are no specific reading interventions routinely offered to support deaf children's reading. In order to raise literacy levels, further research is urgently needed to develop appropriate reading interventions for this group.

Interventions to improve deaf children's reading must address the deficits that underlie poor reading, and principal to these is poor language, since it directly supports decoding skills. For deaf children who sign, a solid foundation in BSL can provide a stepping-stone to acquiring English, and thereafter to age-appropriate literacy. Yet for many, with the notable exception of children in deaf families, the transition from BSL to English appears difficult to achieve. Based on our findings, reading interventions for signing deaf children that emphasize the links between BSL signs and English words and are supported by speechreading are warranted. Moreover, spelling emerged as a relative strength in all deaf children. Spelling involves encoding skills and capitalises on deaf children's visual strengths, both of which may support the teaching of reading, and therefore present a way of accessing phonology and an additional strategy for reading interventions.

We have seen that poor reading is not an inevitable outcome for every deaf child, since some deaf children do succeed in becoming good readers, yet research has shown repeatedly that many deaf children continue to fail at reading. Changes in recent reading test norms indicate that hearing children are now reading better than previously; the same cannot be said for deaf children.

The children in this study were at the end of their primary education; many are ill-prepared for the demands of secondary school. All poor readers are in need of support, and interventions should ideally be implemented early to develop the language skills that underpin literacy and to tackle their phonological deficits to prevent this state of affairs. Our findings highlight an urgent need to implement individualised, intensive interventions known to be effective with hearing children for deaf children who are poor readers. Additionally, the language problems faced by the majority of deaf children must also be addressed, using strategies that target deaf children's strengths to support areas of deficit. With a proper understanding of their reading deficits and appropriate support, the outlook for deaf children can and must change.

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Appendix: Test battery

Target	Test
Nonverbal skills	British Abilities Scales II (BAS II, Elliott et al., 1996) Matrices, Pattern Construction
Reading skills: decoding	BAS II Single Word Reading Test
	Dyslexia Portfolio Non-Word Reading Test (Turner, 2008)
	York Assessment of Reading Comprehension (YARC, Snowling et al., 2009) Letter-Sound Knowledge Test
Reading skills: rate and comprehension	YARC Passage Reading Test: Reading Comprehension
Spelling	BAS II Single Word Spelling Test
Phonological skills	Phonological Assessment Battery (Fredrickson et al., 1997): • Rhyme Awareness Test • Spoonerisms Dyslexia Portfolio: • Phoneme Deletion Test • Recall of Digits Forwards and Backwards Initial Phoneme Matching (James et al., 2008) Non-word Reading (Sterne & Goswami, 2000)
Naming speed & fluency skills	Phonological Assessment Battery: • Naming Speed Test (pictures, digits) • Fluency Test: Rhyme, Semantic (non-phonological)
Language skills: expressive vocabulary	Expressive One Word Picture Vocabulary Test (Brownell, 2000) - English and BSL elicited separately
Speech intelligibility	Speech Intelligibility Rating Scale (Allen et al., 2001)
Speechreading	Test of Child Speechreading (Kyle et al., 2013)
Sequential organisation skills	Recall of sequences: days of the week, months of the year