Spelling in oral deaf and hearing dyslexic children: A comparison of phonologically plausible errors

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Abstract

A written single word spelling to dictation test and a single word reading test were given to 68 severely-profoundly oral deaf 10-11 year old children and 20 hearing children with a diagnosis of dyslexia. The literacy scores of the deaf children and the hearing children with dyslexia were lower than expected for children of their age and did not differ from each other. Three quarters of the spelling errors of hearing children with dyslexia compared with just over half the errors of the oral deaf group were phonologically plausible. Expressive vocabulary and speech intelligibility predicted the percentage of phonologically plausible errors in the deaf group only. Implications of findings for the phonological decoding self – teaching model and supporting literacy development are discussed.

Highlights

- Literacy scores of deaf and hearing dyslexics were below expected levels and did not differ
- Analysis of spelling errors revealed marked between group differences in PPE
- PPE was associated with literacy outcomes in both groups
- Vocabulary was a strong predictor of PPE in the deaf children only
- Deficits were discussed in terms of the phonological decoding self-teaching model

PPE: Percentage of phonetic errors

1. Introduction

It is well documented that children who are born deaf or who are deafened before they learn to talk experience difficulty in acquiring literacy skills (Traxler, 2000; Wauters, van Bon & Tellings, 2006) and that the gap in performance between deaf and hearing children widens with age (Harris & Terlektsi, 2011; Kyle & Harris, 2010; 2011). Although literacy includes reading and writing, the vast majority of studies have focussed exclusively on deaf children's reading ability. Fewer have been concerned with the area of deaf children's spelling, despite research indicating that, at least for hearing children, there is a relationship between spelling and learning to read (Frith, 1985).

Colombo, Arfe & Bronte (2012) note in their study of phonological mechanisms in written spelling in profoundly deaf children that 'the ability to form a well-defined and robust representation of the phonological structure of words, and the consequent knowledge of their sound components is a prerequisite for the acquisition of literacy' (p.2022). Deaf children's reduced auditory access to the spoken word has consequences for the development of robust phonological representations resulting in comparatively poor phonological skills and literacy (e.g. Leybaert & Alegria, 1993; Ormel, Hermans, Knoors, Hendriks & Verhoeven, 2010), However, information derived through speech reading (lipreading or visual speech processing) is known to play an important role in supporting deaf children's acquisition of phonological skills and reading and spelling development (Harris & Moreno, 2006; Kyle & Harris, 2006, 2010; Kyle, MacSweeney, Mohammed & Campbell, 2009). Deaf children (Wakefield, 2006) and hearing children with severe phonological deficits (McNeil & Johnston, 2008) rely more than their typically developing hearing peers on visual, orthographic skills, either as a compensatory strategy and/ or to capitalise on their relative strengths. Other researchers have highlighted the importance of other key skills to literacy outcomes in deaf children, including vocabulary and language skills (e.g. Geers & Moog, 1989; Kyle & Harris, 2010; Mayberry, del Giudice & Lieberman, 2011).

It has been suggested that the stages of learning to read and learning to spell may have a reciprocal relationship and that progression in the early stages of reading can help the child progress in the early stage of spelling. As spelling ability develops, this, in turn, positively affects progress in reading (Frith, 1985; Westwood, 2005). This is evident in the strong positive associations usually observed between reading and spelling ability in typically developing children (e.g. Bishop, 2001; Caravolas, Hulme, & Snowling, 2001), but higher quality lexical representations are more important for accurate spelling than reading (Perfetti, 1997). To gain understanding of the kinds of strategies involved in decoding and recoding the written word, researchers have analysed children's reading and spelling errors. Such studies are informative as they provide a window into the strategies children use and the extent to which the phonological route is adopted (Greenberg, Ehri & Perin, 2002; McGeown, Medford & Moxon, 2013). The analysis of spelling errors is a more reliable method for deaf children with poor intelligibility as it is not dependent on the quality of speech production.

Although developmental stage models of spelling may differ in their terminology and number of stages, in general they suggest that typically developing children progress through a series of increasingly sophisticated stages as they advance through school (Ehri, 1992; Frith, 1985; Mayer, 2007). Certain errors can be symptomatic of a certain stage / stages and could point to spelling delay or disorder. In the early stages errors are undifferentiated, but between the ages 7 and 11 years, typically developing children show a high reliance on phonetic spelling (Frith, 1985). Bishop & Clarkson (2003) found a steady increase in the proportion of phonologically plausible errors made by typically developing children aged 7-13 years, comprising about half of the spelling errors in the youngest age group and three-quarters of the misspellings of 12 year olds. Similarly, McGeown et al., (2013) found that two thirds of their sample of 7 year old typically developing children used phonological strategies for reading and spelling according to their error analysis of irregular words. Strategies children used were mixed, but most showed some preference and exclusive use of either a phonological or orthographic (visual) strategy for spelling was relatively rare. Only a small percentage (4%) made sole use of a phonological strategy for spelling, compared with nearly a quarter of the sample (22.3%) for reading. Both phonological and orthographic spelling strategies were predicted by an independent measure of decoding. These findings, together with children's variable strategy use, are in line with Share's (1999) self-teaching hypothesis that underscores the critical role of item-by-item phonological decoding skills for the acquisition of word specific orthographic representations in reading. More recently the self-teaching role of spelling has been highlighted, which like decoding 'requires close attention to letter order and identity as well as to word-specific spelling-sound mappings' (p.22, Shahar-Yames & Share, 2008).

Literacy, both spelling and reading, depends not only on a child's age and developmental stage, but other factors such as exposure to print, teaching methods, and the nature of a child's native language, in particular the degree of correspondence that exists between phonemes (speech sounds) and graphemes (letters, or sequences of letters). Opaque orthographies such as English or French have a high proportion of irregular words, compared to transparent, regular orthographies such as Italian, which present additional challenges to the young learner. Spelling in all alphabetic languages relies heavily on intact phonological abilities, but opaque orthographies demand much more specific knowledge of the written language involved that is acquired across time (Share, 2004).

Dyslexic children like deaf children have deficits in processing phonological information that compromise their decoding skills affecting their reading and spelling abilities (Hulme & Snowling, 2013), but studies investigating reading ability in dyslexic children far outnumber those looking at spelling; even though the majority of individuals with dyslexia are found to have spelling difficulties too (Wimmer & Mayringer, 2002). Across the early school years the proportion of phonologically plausible errors that dyslexic children make increases, although the overall spelling error rate still remains higher than expected for children of the same age, and the proportion of phonologically plausible errors is lower than expected, particularly in opaque orthographies. For example, Wimmer (1996) found that a small sample of 1st grade German speaking children with dyslexia could not spell a single nonword and most of their misspellings were phonologically implausible. Three years later in the 4th grade, although still dysgraphic, the majority of their errors in this relatively shallow orthography were phonologically plausible. Likewise, Angelelli, Notarnicola, Judica, Zoccolotti, and Luzatti (2010) in a follow-up study of 33 Italian dyslexic children in 3rd grade found they produced a high rate of all types of errors, but by 5th grade most of their errors were phonologically plausible. A recent study investigated 26 French-Canadian dyslexic children aged 9-12 years (mean age 11.2) in comparison with 26 chronological age (CA) matched controls and 29 reading age (RA) (mean age 7.9) matched controls. Using a free production spelling task, they found the dyslexic group's performance was more commensurate with the younger RA group than the CA group, with a mean percentage accuracy score at word level of 43.5% (dyslexic group), 61.13% (CA group) and 82.45% (CA group) (Plisson, Diagle & Montésino-Gelet, 2013). Adopting a binary system to classify phonological errors as either plausible or not plausible, about three quarters of the errors of the 11 year old dyslexic group and the younger RA controls were phonologically plausible (74.57% and 75.68% respectively) compared with nearly nine tenths of the CA group (88.12%).

The question of whether deaf children employ phonological strategies when attempting to spell target words has been addressed by research studies with somewhat conflicting results. A number of UK and US studies based upon spelling error analysis found little evidence of phonological strategies being used indicating that deaf children were not relying upon phonological coding when spelling (e.g. Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Harris & Moreno, 2004; Olson & Caramazza, 2004; Sutcliffe, Dowker & Campbell, 1999; Wakefield, 2006). The studies covered a wide range of ages and mixed communication backgrounds, with oral children in the minority. Wakefield (2006) for example, found the majority of her mixed sample made between 80-100% non-phonetic errors. Their errors showed reliance on a visual strategy and included order 'anagram' style errors (e.g. cicrle for circle). A small minority, whose performance set them apart from the rest of the group, made less than 40% of non-phonetic errors. These children were all aurally educated and had mild-severe hearing loss.

However, other researchers have provided evidence that deaf children are able to use a phonological code when spelling. Dodd (1980) used a non-word spelling task with profoundly deaf teenage participants who were encouraged at school to lip read (speech read) and use oral communication. She reported that her participants could use a phonological code to generate spellings of nonwords, which she attributed to the deaf students' lip reading ability.

In a later study, Harris & Moreno (2006) found that good deaf readers had higher spelling scores, more often represented the correct number of syllables and had a significantly higher proportion of phonetic errors in their spellings than poor deaf readers. The authors suggest their results indicate that some deaf children can use a phonological code to spell and, because the proportion of phonetic errors was correlated with speechreading skills, proposed that their phonological code may be derived from speech reading.

Leybaert (2000) compared groups of deaf French participants aged 6 -14 years with varying exposure to and knowledge of Cued Speech, a way of visually representing the sound structure of spoken language and disambiguating lip patterns (Cornett, 1967). She found that deaf participants who used Cued Speech at home rather than simply at school, and therefore had a richer Cued Speech environment, made a majority of phonological errors in their spelling (Leybaert, 2000). Results from Leybaert's study suggest that deaf children do need phonological input in order to use phoneme-grapheme mappings, but that this need not be based solely on auditory input. More recently, Colin, Leybaert, Ecalle & Magnan (2013) in a longitudinal study of literacy skills in deaf children with different exposure to Cued Speech found no differences in the number of spelling errors made by 8 year old deaf children with early pre-kindergarten exposure to Cued Speech compared with age matched hearing children. In both cases the majority of errors were phonologically plausible, although marginally higher in the hearing group (82% compared with 68.3% on average). In contrast, late exposure to Cued Speech (kindergarten or later) was associated with significantly poorer spelling, where the minority of errors, less than a quarter, were phonologically plausible. However, there were individual differences; some late exposure CS children with better speech intelligibility had phonological error scores within the confidence limits of the hearing controls.

Hayes, Kessler & Treiman (2011) study of 39 profoundly deaf English speaking children with cochlear implants, 6-12 years, mean age 8.97 years, found their spelling was less accurate compared with CA hearing children, but did not differ after controlling for reading differences. However, a higher proportion of the spelling errors of the hearing group were phonologically plausible (75% vs. 44% deaf children with CI), a difference that was not accounted for by differences in reading levels. They found that gender, parental education levels and age of implantation had no significant effect on the rate of plausible errors.

Likewise, Harris & Terleksti (2011) found no effect of age of implantation on the spelling performance of deaf adolescents with cochlear implants but more surprisingly, they also reported no differences between the cochlear implant users and those with digital hearing aids.

It is important to note that whilst some of these studies have been based on deaf participants who communicate using either speech or sign, others have included participants with a variety of communication preferences. It is likely that these differences may to some extent explain the conflicting findings. For example, where explicit comparisons have been made between oral and signing participants, results indicate that the communication mode influences the use of phonological recoding in reading (Miller, 2002) and in spelling (Wakefield, 2006). These studies suggest a strong link between oral abilities (which generally rely on speech reading) and spelling.

There are several methodological issues that arise when assessing spelling ability in deaf children. The majority of studies investigating deaf children's spelling abilities tend to use a spelling-to-picture or spelling-to-sign test format. However, testing spelling using a pictorial format relies on the pictures being easily identifiable and the participant producing the word that the assessor intends. Using pictures, it is also difficult to ensure that spelling tests contain target words from all word classes and therefore these spelling assessments tend to be limited to concrete nouns rather than verbs and plural nouns. Testing using a spelling-to-sign format makes the words easier to access for a deaf child with competent signing skills but raises other issues, such as regional variation in sign, differing levels of signing ability in the deaf population, as well as the fact that there is often no direct translation between a sign and the spoken equivalent. Alternatively, using a sign combined with a lip pattern to disambiguate between meanings, as is often found in BSL (Brien & Brennan, 1992), could give additional visual phonetic information to help the participant spell the word, making some words easier to spell than others.

With earlier identification of deafness, better digital hearing aids and earlier use of cochlear implants, increasing numbers of deaf children in the UK are now educated in mainstream schools or in units attached to mainstream schools than previously (CRIDE, 2013). Moreover, in recent years in the UK, children are explicitly taught using targeted phonics-based strategies, strategies that have been shown to improve deaf children's reading abilities (see Trezek & Malmgren, 2005). In the light of the above, the decision was made to employ a widely used standardised spelling-to-dictation test in the present study of oral deaf children, the method that is most commonly adopted for testing spelling in hearing children.

1.1. The current study

The current study aimed to analyse the spelling skills of a large, representative sample of orally educated prelingually severely-profoundly deaf children using a spelling-to-dictation task and a single word reading task taken from the British Ability Scales 2nd Edition (BAS II, Elliott et al., 1996). Deaf children's scores were compared with hearing children using test norms and in addition with a small group of hearing children diagnosed with dyslexia. Spelling errors were analysed using the error classification described in the BAS II to determine the percentage of phonetic errors. The study sought to address the following research questions:

1. Are there differences in spelling between deaf children who use hearing aids in comparison with those using cochlear implants?
2. Using the test standardisation, how does deaf children's spelling compare to hearing children with and without a diagnosis of dyslexia?

3. Based on an analysis of spelling errors, do oral deaf children and hearing children with dyslexia differ in the percentage of phonetic errors made?
4. Based on an analysis of spelling errors, how does spelling strategy relate to spelling and reading outcomes in oral deaf and hearing dyslexic children?

2. Method

2.1. *Participants*

2.1.1. *Deaf participants*

Prelingually deaf children who communicated orally and who were in their final year of primary education (Year 6) were recruited throughout the UK from special schools and services for children with hearing impairment and through contact with mainstream primary schools. The criteria for selection was that each child had a severe-profound bilateral hearing loss as defined by the British Society of Audiology (BSA, 1988) and had no co-occurring difficulties (such as a severe developmental or visual impairment) which would make participation in the assessment tasks difficult. Teachers and Special Educational Needs coordinators confirmed that pupils who were referred met these criteria.

Of 98 children referred, 15 were not included as it later emerged that they had a mild-moderate level of loss. Four children were excluded because they were unable to complete all measures. The final sample comprised 79 children who met all the recruitment criteria. This sample size represents almost 40% of the population of severe-profoundly deaf children in the target age range in the UK (Davis et al., 1997). For the current paper a further ten deaf children who achieved scores below the normal range on an average of the two non-verbal IQ tests were excluded. This was to enable comparisons with the hearing dyslexic participants who all achieved nonverbal IQ scores within the normal range. There was missing spelling data on one other child, making a final sample of 68 oral deaf children under consideration here.

The mean age was 11;0 (SD 4.4, range 10;1-12;3) and over a half (57%, n=39) were girls. All children tested preferred to use spoken English as their main means of communication, although some also had knowledge of BSL (n=8) or other spoken languages (n=6). Forty-three children were cochlear implant users, 25 used digital hearing aids.

It was established that children were oral communicators through discussion with their teachers in advance and by asking each child how they preferred to communicate (signing, speaking or both) before starting the assessment. Only one child was reported to be a balanced bilingual, i.e. a fluent user of BSL as well as a competent oral communicator. Although all types of educational establishments were targeted in the recruitment process, the participants came from either units for the hearing impaired (n=52) or mainstream schools (n=16) (see Table 1 for participant details).

2.1.2. Hearing dyslexic participants

Twenty hearing children with either a diagnosis of dyslexia or suspected dyslexia were recruited in England either through mainstream schools, specialist schools for dyslexia, via parents who volunteered their children directly for inclusion in the project or via researchers who had recently worked with families of children with dyslexia.

The mean age of the children was 10;1 (SD=7.78, range 8;9-11;9) and there were equal numbers of boys and girls. Fifteen children were monolingual English speakers, one child had another spoken language at home and data were missing for four participants. The children were on average a year younger than our sample of oral deaf children, and the range of ages wider. However, all our measures are standardised and standard scores were used throughout the analyses. Moreover we were more interested in comparing profiles of performance between our oral deaf and hearing dyslexic groups, particularly the relation between phonological and literacy skills, and less concerned about the comparison of their absolute levels of achievement on literacy measures. The two groups did not differ in their nonverbal scores (Mann Whitney, z=-.38, ns). Table 1 displays relevant participant background details.

Insert Table 1 around here

2.2. Materials

This study was part of a larger research project aimed at developing normative data for deaf children on a large battery of reading and reading related assessments. In addition to this, as part of the larger study, it was intended to research whether a dyslexic profile existed in the less able deaf readers similar to that of hearing dyslexic children. Children in this study were therefore assessed on a range of other tests in addition to the measures described below.

Data are presented here from the following tests from the British Ability Scales II (BAS II, Elliott et al., 1996): two non-verbal subtests (Matrices and Pattern Construction); Spelling and Single Word Reading.

All participants completed the Matrices and Pattern Construction subtests of the BAS II and an average non-verbal percentile score was obtained using these two measures. The Single Word Reading test consists of an A4 card containing printed words and children are asked to read each word aloud. Allowance was made for deaf children's speech patterns.

The BAS II Spelling test is an orally delivered standardised assessment of single regular and irregular word spelling. Some words are high frequency (HF) and some low frequency (LF), with syllables ranging from one to five. The nature of the item (either HF/LF or regular/irregular) is likely to influence children's spelling strategy. For example, spelling by 'sight', using an orthographic strategy is better suited to HF earlier items, than later, less familiar (LF) items which are more challenging and more reliant on phonological skills. As noted above, a spelling to dictation procedure was considered appropriate for the oral deaf children in the present study as all were either educated within an oral unit or mainstream primary school and all had a preference for using spoken English in communication.

The target items consist of single syllable through to 5 syllable words depending on how far the child progresses with the test. Children were told that the assessor would say a word, then use it in a sentence, and finally repeat the word. Children were instructed to write the word down on the appropriate line of the provided spelling sheet. Children were told that they should carefully check what they had written and change it if they felt they had made a mistake. Children were allowed to ask for one repetition of each item if necessary, but no further information was provided. The spelling errors were analysed according to the BAS II Spelling Diagnostic Error Analysis.

Three further measures used in the study were included in the analyses of this paper. The Expressive One Word Picture Vocabulary Test (EOWPVT, Brownell, 2000) was used as a measure of expressive vocabulary. This is an American test and therefore minor adaptations were made as suggested by Johnson and Goswami (2009) who used this test in their study with deaf children in the UK. For example, the lexical target 'racoon' was changed to 'badger' which is indigenous to the UK; a map of the US was replaced with a map of the UK and a few of the pictures were replaced with more appropriate UK pictures depicting the same target. Children are shown the pictures and asked to produce the correct word for each item. The Test of Child Speechreading (TOCS: Kyle, Campbell, Mohammed, Coleman & MacSweeney, 2013) is a standardised assessment of speechreading that measures speechreading of words, sentences and short stories. It is a video-to-picture matching task in which children are shown silent videos and have to select the picture that best matches what they saw.

The Speech Intelligibility Rating Scale (SIRS, Allen et al., 1993) is a five point speech intelligibility rating scale based on spontaneous sample of speech, with 1 being unintelligible and 5, fully intelligible. Children's speech was rated following a 5 minute conversation about their interests in the middle of the first test session.

2.3. Procedure

Informed written consent was obtained from the children and their parents as well as from the head teacher of the participant's school or head of unit as applicable. Ethical approval for the study was granted from the University Research Ethics Committee. Informed written consent was obtained from the children and their parents as well as from the head teacher of the participant's school or head of unit as applicable.

A researcher experienced in working with deaf children assessed all participants. All assessments took place in a quiet room within each child's school. For some of the hearing dyslexic participants, the assessment took place either in a quiet room in the child's school, in a quiet room in their home or at a designated testing centre.

All tests were administered as directed in the administration instructions to both deaf and hearing participants. No amendments were made to the administration of the tests for the deaf children, although the assessor always made it clear that the test instructions could, if necessary, be presented in BSL or SSE to ensure the child knew what was required of them for the task. However, none of the participants required additional communication support to understand the nature of the task. At no point did the assessor finger spell any of the words or present any of the contextual sentences in BSL or SSE.

2.4. Analysis of spelling errors

Spelling errors were analysed according to the BAS II Spelling Diagnostic Error Analysis to determine the range of spelling error types made and to establish a percentage of phonetic and non-phonetic errors made. Errors were classified into 7 different categories. Where handwriting was unclear, participants were asked to clarify their spellings verbally (to say 'h-o-u-s-e', for example). Errors were classified as shown in table 2.

Insert Table 2 around here

As can be seen in Table 2, error analysis was at the word level and misspellings classified as non-phonetic could contain phonemically correct syllables. One amendment was made to the BAS II spelling error analysis. Whereas the BAS II states that semi-phonetic errors cannot be real words, the authors of this study considered that they could. For example, 'fight' was considered to be a semi-phonetic representation of 'flight'.

A second rater checked 10% of the error sample. Error classification was based purely on the written data. Both raters agreed on the categorisation of items into the seven different categories with a Cohen's Kappa value of 0.69. Both raters agreed on the categorisation of errors into either phonetic (semi-phonetic, basic phonetic and plausible phonetic errors) or non-phonetic errors (pre-spelling, major non-phonetic and non-phonetic order) with a Cohen's Kappa value of 0.94. Continuous and categorical scores were derived. The continuous score was the percentage of phonetic errors (PPE) made out of the total number of errors committed. Continuous scores were then categorised as mainly phonetic (constituting 60% or more of errors), mixed (between 41-59%) and non-phonetic (40% or less phonetic errors).

3. Results

3.1. Literacy performance of oral deaf and hearing dyslexic children

Forty-three deaf children (63%) had cochlear implants and 25 (37%) had digital hearing aids. Table 3 shows the means and standard deviations for spelling and single word reading standard scores according to amplification type and for the oral deaf and hearing dyslexic samples as a whole.

Insert Table 3 around here

Independent t-tests confirmed that the marginal differences in performance of children with cochlear implants and digital aids were not significant ($t_{spelling}$ (66) =-1.34, p=.18; $t_{wordreading}$ (66)=-.4, p=.69). Accordingly, the groups were combined and all subsequent analyses were run on the total sample of deaf children.

Before turning to comparisons of our deaf sample and hearing dyslexic sample we consider the performance of both groups relative to the performance of the normative (hearing) populations, with mean scores of 100 using one sample t tests. As can be seen in Table 3, the standard scores of the deaf children on the two literacy measures were at the lower end of the average range, about .66 SD below the normative mean of hearing children. Single sample tests confirmed their mean spelling and word reading scores were significantly lower than expected for hearing children of the same age ($t_{spelling}$ (67)=-6.98, p<.001; $t_{wordreading}$ (67)=-4.78, p<.001). Likewise, the mean literacy scores of the hearing dyslexic group were significantly lower than their age matched peers ($t_{spelling}$ (19)=-2.59, p=.02; $t_{wordreading}$ (19)=-4.99, p<.001)

Not only were the mean literacy scores of the hearing dyslexic and deaf groups significantly lower than the normative sample, their mean scores looked strikingly similar (see Table 3). A mixed design ANOVA taking literacy measures (spelling and word reading) as the within factor and group (deaf and hearing dyslexic) as the between factor, confirmed that the main effects for group and literacy measure were not significant ($F(1,86)_{group}$=.17, p=.68, η^2=.003; $F(1,86)_{literacy}$=.22, p=.64, η^2=.002). In contrast, the interaction group*literacy type was significant. Paired t tests confirmed significant differences between spelling and reading scores in both groups, but, whereas spelling in the deaf group was a relative strength compared with reading, it was a relative weakness in the hearing dyslexic group (t(67)=2.45, p=.02; t(19)=.-2.22, p=.04). In both groups the correlation between spelling and reading scores was strong and highly significant (deaf r=.84, p<.001; hearing dyslexic r=.81, p<.001). We now consider the types of spelling errors the two groups made.

3.2. *Analysis of spelling errors*

The mean PPE score for the deaf was 52.11% (SD=21.42, range: 7-92) and for hearing dyslexic was 79.81% (SD=15.72, range: 38-100). The difference in mean PPE was significant (t(86)=-5,27, p<.001): with the mean PPE of the deaf children 27.2% lower than that of the hearing dyslexic children. Over a quarter of the deaf group (27.9%) had phonetic scores lower than the lowest score of the hearing dyslexic group (<38), and these low scores were indicative of a predominantly non-phonetic strategy. As a group, the hearing dyslexic made mainly phonetic errors. Not surprisingly, we see this pattern reflected in the different distributions of categorical error scores found in the two groups. Table 4 shows the distribution of spelling errors in the hearing dyslexic and deaf groups. Spelling errors were classified into three groups according to their PPE: mainly phonetic (at least 60% phonetic errors), mainly non-phonetic (40% or less) and mixed (between 40-60%).

Insert Table 4 around here

As can be seen in Table 4, hearing status was related to the kind of spelling errors the children made. The overwhelming majority of hearing dyslexic children (90%) made mainly phonetic errors, with the two remaining children making either mixed or mainly non-phonetic errors. In contrast, the distribution in the deaf group was spread fairly equally across the three error types, with just over a third making mainly phonetic errors. A chi-square analysis confirmed the association between error type and hearing status group was significant ($\chi^2(2)=17.53$, $p<.001$). In line with literacy results, we found that type of hearing aid was not associated with type of spelling errors made and their mean PPE scores did not differ (digital aid *M*=52.87, *SD*=21.94; CI *M*=52.26, *SD*=21.37, t(66)=-.07, p=.94)].

3.3. Associations between PPE and literacy (spelling and word reading) for deaf and hearing dyslexic groups

Figure 1 is a scattergram showing the relation between PPE scores and (A) spelling and (B) reading performance in the deaf group (black dots) and hearing dyslexic (white dots) groups. The Y reference line represents the cut-off score (85) for below average performance on the literacy measures. The two X reference lines represent the cut-off scores for phonetic errors

(60%) and non-phonetic errors (40%), with mixed phonetic errors falling between the two lines (40-60%).

Insert Figure 1 around here

As can be seen in Figure 1 there was an association between phonetic errors and literacy scores, with non-phonetic errors associated with below average literacy scores and phonetic errors with literacy performance in the average range (and see Table 6 below). Three children made phonetic errors only (PPE=100%). These children were all from the hearing dyslexic group (15% of the sample) and had average literacy scores, although their spelling scores were lower. The three children with the lowest PPE (<20%) were deaf and all had low literacy scores. Interestingly the association between mainly non-phonetic errors and literacy was if anything more evident in relation to reading than to spelling. As can be seen the one child in the hearing dyslexic group who fell in the non-phonetic group had an error score close to the cut-off and was one of the poorest readers in the hearing dyslexic group.

Most of the deaf children who made mainly phonetic errors had spelling and reading scores in at least the average range. The literacy performance of those with mixed error profiles was more variable. The effect of error profiles on literacy was examined further through univariate ANOVAs, taking the 3 way categorical measure of error type as the independent variable. Table 5 shows the descriptive and inferential statistics, including effect sizes (partial eta squared) for spelling and reading performance according to spelling error profile. As expected from the above results, the differences in literacy scores associated with error type were highly significant. All effect sizes were large (>.14) (see Table 5).

Insert Table 5 around here

Post hoc analyses, applying Bonferroni correction for multiple comparisons, showed that there were no significant differences in the literacy scores of children who made mainly phonetic errors or mixed errors. The spelling and reading scores of children who made mainly phonetic errors were significantly higher than those of children who made primarily non-phonetic errors ($p=.002$ and $p<.001$ respectively), whereas the difference in literacy scores between those who made mixed phonetic errors and those with mainly non-phonetic errors was significant for reading performance only ($p=.01$ and ns respectively). This within group analysis was carried out in the deaf group only, as the vast majority of the hearing dyslexic sample (90%) made mainly phonetic errors. However, as can be seen in the Figure 1, the literacy scores of the two hearing dyslexic children who made mainly non-phonetic errors or mixed errors were in line with the deaf profiles. The child who fell in the mixed error range with a score close to the cut-off for mainly phonetic errors had literacy scores in the average range, albeit at the lower end, whereas both reading and spelling scores of the hearing dyslexic child who made mainly non-phonetic errors were below average. It is important to note that most children made both phonetic and non-phonetic errors to a greater or lesser extent. We return to the question of how well our PPE measure maps onto phonological and orthographic spelling strategies in the discussion.

Finally we consider the impact of speech reading and speech production skills (both of which are known to be associated with literacy performance in deaf children) on the type of spelling errors made, controlling for vocabulary. Table 6 shows the correlation between PPE and literacy, expressive vocabulary, nonverbal skills and speech reading and speech production/intelligibility (deaf sample only). Speech intelligibility was assessed in the deaf group only. As our main concern here is the relation between continuous scores, we have included descriptive measures of the additional measures as a footnote to the Table 6. Between group differences will be reported in a separate paper.

Insert Table 6 around here

As can be seen in Table 6, PPE in the deaf group was significantly associated with both literacy measures, expressive vocabulary, and speech production /intelligibility. In all cases the correlations were moderate to strong. In contrast the only significant association in the hearing dyslexic group was between PPE and reading. The association with spelling fell short of significance, mainly due to the narrower range of spelling scores compared with reading. In contrast to the deaf group, expressive vocabulary was unrelated to spelling error type and the marked difference between the correlations was significant (Z=2.47, p=.007). In both groups, there was a small association with nonverbal skills (reaching borderline significance in the larger deaf group), but no significant association with speech reading skills in either group. In the deaf group the correlation between expressive vocabulary and speech production was also moderately strong (r=.51***). Accordingly a multiple regression analysis was run to determine if speech production added significantly to the amount of variance explained in PPE, once vocabulary performance had been taken into account. Nonverbal skills were of borderline significance and also included in the model. Table 7 shows the results of this analysis.

Insert Table 7 around here

As can be seen in Table 7, speech intelligibility, but not nonverbal performance added significantly to the model, explaining an additional 8% of variance once expressive vocabulary scores had been taken into account. The total model accounted for just over a third of the total variance in percentage error scores, leaving two thirds unexplained. Nonverbal performance did not add significantly to the model.

Insert Figure 2 around here

Figure 2 shows the association between PPE and expressive vocabulary according to speech intelligibility. For the purpose of the scattergram the 5 point intelligibility was reduced to a 3 point scale, with the lowest two levels combined to represent ‘poor’ intelligibility, the highest two levels expressed as ‘good’ with the middle grade remaining as a single ‘moderate’ rating of intelligibility. Three children were rated as ‘low’ intelligibility (4.4% of deaf group), 14 (20.6%) ‘moderate’, and 51 (75%) ‘good’. As expected from the previous correlations, the associations between phonetic error (3 way) and vocabulary (2 way, below average (<85) and average range) and phonetic error and intelligibility (3 way) were significant (Fisher’s exact =18.52, p<.001 and 17.37, p=.001, respectively). 95 % of those who made mainly non-phonetic errors had below average vocabulary, compared with just over a third (36%) of those who made mainly phonetic errors. The majority (92%) of those who made mainly phonetic errors had ‘good’ intelligibility and none had ‘poor’, compared with just over two fifths (43%) of those who made mainly non-phonetic errors with ‘good’ intelligibility. In addition the association between intelligibility and vocabulary was significant (Fisher's exact = 12.49, p=.001). As can be seen from the scattergram,'good' intelligibility was a necessary but not sufficient condition for vocabulary scores in the average range. All those with vocabulary scores in the average range had 'good' intelligibility compared with just over half (55%) of those with below average vocabulary scores. As can be seen in Figure 2, only one child with average vocabulary scores and 'good' intelligibility made mainly non-phonetic errors.

4. Discussion

This study utilised a standardised spelling to dictation test with a group of oral deaf 11 year old children in their final year of UK primary school. These children had been exposed to at least five years of formal education and literacy instruction. All children were able to access the test, although in line with previous research, scores on this measure and for single word reading were significantly poorer than hearing children, as measured by the test norms. Like Harris & Terleksti (2010) we found no differences in the literacy scores of children with cochlear implants (CI) and those with digital hearing aids, so these groups were not considered separately in our analyses. This failure to find differential outcomes according to type of amplification is not necessarily a reflection of the potential capacity of CIs, rather it may be an indication of advancements made to digital aids in recent years. The picture may change with very early implantations carried out in the first year to 18 months of life, a period known to be critical for the development of phonological skills and language specific phonology (Kuhl et al., 2006). However, our sample, like many other studies involved CIs carried out across a number of years, the majority of which occurred after 2 years of age. This mixed CI history may have contributed to our finding that children's use of the phonological route as measured by PPE, like their literacy performance, was not related to amplification.

As a whole, the deaf group's literacy scores were strikingly similar to those of a comparison group of hearing dyslexic children, matched on nonverbal skills, who like our deaf children performed below the level expected of their age (about three quarters of a SD lower). Spelling was a relative strength for the deaf children and relative weakness for the hearing dyslexic children, but the differences although significant were marginal. For both groups, spelling was highly correlated with single word reading; almost identical in size to the correlation (r=.84) found for a sample of 155 hearing children (Bishop, 2001) and deaf children (r=.88) (Kyle & Harris, 2006). In line with previous research, our poor spellers were also poor readers. However despite these apparent similarities in literacy levels, the error analyses revealed marked differences in the extent to which the deaf and hearing dyslexic groups used the phonological route to spell single words.

Nearly three quarters of spelling errors for the hearing dyslexic group were phonologically plausible, compared with just over half the errors of the oral deaf group; percentages which are very much in line with previous findings for hearing dyslexic and oral deaf children of this age (Hayes et al., 2011; Plisson et al., 2013). Bearing in mind that our hearing dyslexic group were younger, and that PPE increases with age, it is likely that this is a conservative estimate of the overall differences in spelling strategies. However, the size of the difference only matters if different strategies, as indicated by error patterns, relate systematically to literacy outcomes.

As a first step however, we need to consider the extent to which PPE, maps onto phonological and orthographic strategies widely referred to in the literature. We selected PPE as a proxy measure of children's use of the phonological route but the extent to which BAS non-phonetic categories can be seen as tapping orthographic skills varies. The role of orthographic skills in 'non-phonetic order 'errors is much clearer than for 'major non-phonetic' where according to BAS criteria there is limited evidence of the use of either strategy. Many of our deaf children, like the children in Wakefield's (2006) study, made non-phonetic order 'anagram' errors indicative of using an orthographic strategy, but substantially more of their errors were classified as 'major non-phonetic errors (e.g. fisteted for 'physicist'). The initial use of a phonological strategy with little evidence of a visual, orthographic approach suggests the word 'physicist' was novel to the child concerned and the misspelling illustrates the additional challenges to literacy that deaf children face. Their weak oral vocabulary exacerbated by and associated with poor literacy skills and less exposure to print, means that as spelling target words increase in difficulty they are likely to be unfamiliar to the deaf child. As an orthographic strategy requires previous exposure to the printed word, a phonological strategy is mandatory, if not sufficient, for decoding and recoding novel words (Share, 1999). Accordingly we see PPE primarily as an indirect measure of children's use of phonological strategies.

~~Whilst the PPE was based on children's spelling, the correlation with reading was if anything somewhat stronger in both groups. In terms of continuous performance, spelling was moderately and significantly associated with PPE in the deaf group only; the small correlation found in the hearing dyslexic group did not reach significance. In contrast, the association between reading and PPE was significant in both groups, and was marginally stronger than the association with spelling in the deaf group, suggesting that phoneme to grapheme translations are marginally more reliant on sub-lexical skills than grapheme to phoneme.~~

The distribution of categorical PPE scores was also extremely informative. The overwhelming majority (90%) of the hearing dyslexic group made mainly PPE, of which nearly two fifths (38%) were poor spellers (standard scores <85) and just over a quarter (28%) were poor readers, showing phonological deficits typical of children with dyslexia. Of the remaining two children, one had a mixed profile of errors with average literacy scores; the other child made mainly non-phonetic spelling errors and was a weak speller and reader. In contrast, there was an almost equal distribution of scores across the three error categories in the deaf sample. Once again, a mainly non-phonetic strategy was associated with the weakest literacy performance: nearly three quarters were poor spellers (71.4%) and four fifths were poor readers (81%). A subsample of five children (<25%) with exceptionally low proportions of PPE were the poorest readers and spellers in the deaf sample. Whereas a minority of the deaf group making mainly phonetic errors had poor literacy problems, two (8%) were poor readers and three (12%) poor spellers, i.e. showing a more typically dyslexic profile.

The group making predominately mixed phonetic errors used the phonological route, but less consistently, and drew on other strategies as well. Their greater reliance on mixed strategies compared with the hearing dyslexic children underscores their use of a visual/orthographic strategy to compensate for their compromised access to phonological information due to their hearing loss. This mixed strategy was better suited to spelling where just over a quarter (27.3 %) were below average, but reading outcomes were poorer. Over half of the mixed group (54.5%) had below average reading scores. Taking the dual model (Coltheart, 2005), our evidence suggests that relying more on a lexical than a sub-lexical route may be a less efficient strategy for reading, involving phoneme-grapheme correspondence, but may be less problematic for spelling where graphemes are the starting point. This interpretation may explain why deaf children typically show more severe delays in reading ability compared with spelling ability (e.g. Burden & Campbell, 1994; Geers and Moog, 1989). In contrast, the hearing dyslexic group overwhelmingly adopted a phonological strategy to spelling, irrespective of impairments in this route.

Whilst the distribution of phonetic and non-phonetic errors was relatively equal for children making mixed phonetic errors, *all* children (with the exception of three from the hearing dyslexic group) adopted mixed strategies to a greater or lesser extent. A range of factors including the nature of the stimuli (regularity/familiarity), age of children (Bishop & Clarkson, 2003), type of literacy instruction (McGeown, Johnston & Medford, 2012) and weak literacy skills (McNeil & Johnston, 2008) have been shown to be related to strategy use in hearing children. This shifting strategy is seen to be adaptive (Rittle-Johnson & Siegler, 1999), with children making implicit choices on an item by item basis according to the nature of the stimuli and their own skills set. Deficits in key skills, depending on their nature and severity, inevitably limit choices and accuracy of performance. Evidence from our sample and from studies of hearing children (McNeil & Johnston, 2008) suggests that over-reliance on an orthographic strategy is not an efficient strategy for most children and associated with the weakest literacy outcomes.

Finally, we turn to within child factors that might underpin strategy selection by considering possible predictors of PPE, which from the literature are known to be associated with phonological processing and literacy outcomes in deaf children (Colin et al., 2013; Kyle & Harris, 2006. 2010). In the deaf group, vocabulary and speech intelligibility but not speech reading, were significantly associated with PPE. In contrast, none of these predictors were associated with PPE in the hearing dyslexic group: the correlation with vocabulary was close to zero and significantly lower than the moderate correlation found in the deaf group. This finding is in line with recent evidence from hearing children where expressive vocabulary was unrelated to decoding, text reading and regular word reading (Ricketts, Nation & Bishop, 2007).

The lack of association with speech reading was surprising and is not in line with consistent evidence of its association with reading outcomes in younger deaf children (e.g. Arnold & Kopsel, 1996; Kyle & Harris, 2010; 2011; Kyle et al., 2009) and deaf adults (Mohammed, Campbell, MacSweeney, Barry & Coleman, 2006). However, it is important to emphasise we are looking at PPE here and not the association with literacy outcomes, which will be explored further in other papers. Interestingly, like adults with dyslexia (Mohammed et al., 2006), our hearing dyslexic group did relatively poorly on this task, but like the deaf group their speech reading was not related to PPE.

Regression analyses confirmed the key role of vocabulary in the deaf group, explaining more than a quarter of the variance in PPE, whereas non-verbal ability was not significant once the other factors were taken into account. Interestingly, speech intelligibility also added significantly, explaining an additional 8% of the variance in PPE. Evidence from hearing children shows that speech production problems are most apparent in the preschool years and on their own are not associated with weak language skills or poor outcomes. However, children with combined speech and language problems, the case for many of our deaf group, are at the highest risk of the most severe problems (Pennington & Bishop, 2009). Although the aetiology of speech problems in deaf and hearing children is clearly different overall, as Pennington & Bishop point out children with co-occurring problems are at greater risk as they are likely to have fewer compensatory strategies at their disposal. Further, Hulme & Snowling (2013) note children's critical dependence on phonological speech sound skills for decoding, citing Mattingly (1972, p.133) 'reading is parasitic on speech'. Like Colin et al.'s (2013) findings with Cued Speech, our evidence suggests although deaf children's phonological representations may be largely dependent on non-acoustic experiences, with lip-reading being particularly important at least in the early years, speech production and experiences of speech sounds may also be significant. In our sample, good intelligibility was associated with the likelihood of using phonological strategies and higher vocabulary. However, the relation between speech intelligibility and phonological representations in deaf children is unlikely to be uni-directional.

Oral language and vocabulary at the lexical level is key to literacy and reading comprehension in hearing children (Gough & Tunmer, 1986; Hulme & Snowling, 2013).

What is particularly novel from the current study is the finding that for deaf children, but not for hearing children with dyslexia, expressive vocabulary was significant at the sub-lexical level and related to the extent children used the phonological route for both spelling and reading. We should emphasise that our sample under consideration here were oral deaf children; we are currently investigating the extent to which these findings apply to signing deaf children of the same age. For our oral deaf sample, using the phonological route was integral to literacy competence.

Vocabulary size was a key feature in a recent computational model of reading that tested out the phonological decoding self-teaching (PDST) hypothesis of reading (Share, 1995). As noted, Share argued that a self-teaching mechanism or 'built-in teacher' of reading exists in all alphabetic writing systems and word-specific orthographic information is systematically built up through successful decoding of unfamiliar words. The computational PDST model (Ziegler, Perry & Zorzi, 2013) was much more successful than simulations of previous connectionist models that relied on an 'external teacher' supplying the pronunciation of all words to be learnt. Despite irregularities, the PDST model was able to learn up to 80% of the words based on limited pre-training with a small number of phoneme-grapheme correspondences. However, a key assumption of the model was that children know a large number of spoken words prior to reading and a phonological lexicon is an integral part of the PDST model. Poor vocabulary (small phonological lexicon) was one of a number of factors, including for example underspecified representations, that was responsible for phonological deficits affecting the functioning of the PDST model and children's acquisition of word recognition. According to this model, preschool children with weak vocabulary are not well equipped to make use of their self-teaching literacy skills. In the hearing population, children from socio-economically deprived backgrounds whose compromised early language environment is associated with weak early language skills (Roy & Chiat, 2013) are likewise at risk of poor literacy outcomes (Flus et al., 2009).

4.1. Limitations

Our comparisons of spelling strategies and their relation to literacy were between two groups known to have phonological impairments due, in the main, to different aetiological factors. We achieved our aim of recruiting a substantial sized group of oral deaf children in their last year of primary education in the UK. This gave our study a degree of statistical power and homogeneity that is rarely found in studies of deaf children. However, our resources did not allow for the inclusion of reading and spelling aged matched and/or chronological aged matched typically developing controls (see for example, Harris & Moreno, 2004). As a result comparisons of our results with children with intact phonological systems were limited to normative data available for literacy scores and findings from existing studies where literacy measures, methods of spelling error analyses and age of children may not be directly comparable with ours. A further limitation of our study is the lack of an analysis of reading errors which has been shown to be informative in hearing populations, not least in showing different relations to literacy outcomes compared with a measure of spelling strategy (McGeown et al., 2013). Our decision to focus on spelling errors only was determined in part by the nature of the two tasks. As noted, the variable levels of intelligibility amongst deaf children in general and those in our sample in particular make the analysis of reading errors less reliable than analysis of written spelling errors where the problem of intelligibility does not arise.

4.2. Summary and implications

Despite below average literacy performance and weak vocabulary skills, poor literacy skills were not an inevitable outcome for the oral deaf group; those with better literacy skills were more likely to use the phonological route, as evidenced by their PPE, which in turn was associated with richer oral vocabularies. Furthermore, as the hearing dyslexic group showed, the phonological route to spelling does not necessarily lead to better literacy skills: the association between PPE and spelling was small and non-significant in the hearing dyslexic sample. Arguably the hearing dyslexic group, the majority of whom had received intervention for their reading difficulties, showed an over-reliance on phonological spelling that in the long-term can interfere with orthographic lexical acquisition (Angelelli et al., 2010). Reading difficulties irrespective of hearing impairment, limit exposure to written words and self-teaching opportunities hampering the development of well-formed lexical representations. Nevertheless the potential of spelling to support children's literacy development has been highlighted in both hearing (Ehri, 2014) and deaf children (Hayes, Treiman & Geers, 2014). Ehri (2014) found that spelling facilitated new vocabulary learning and suggested this was due to spelling strengthening phonological representations in memory. Further, Hayes et al.,(2014) pointed out the value of analysing spelling errors in teaching spelling to deaf children thereby providing opportunities for explicit learning that are not otherwise available to them. We agree, and in addition suggest that Zeigler et al.'s PDST model help in identifying the level of breakdown by highlighting different reasons for phonological deficits including 'poor vocabulary (a small phonological lexicon), noise in the phonological lexicon, underspecified phonological representations or phoneme deficits' (p.8). Whilst we have shown that specific deficits may underpin the literacy difficulties of specific groups, it is likely that some children will have additional deficit(s) thereby limiting their use of alternative strategies and affecting the nature, severity and persistence of their problems.

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Table 1: Participant details

Characteristic	Deaf (n=68)	Hearing Dyslexics (n=20)
Mean Age in months (SD)	132 (4.4)	121 (7.78)
Mean Nonverbal percentile (SD)	47.72 (18.43)	51.80 (25.05)
Gender		
Male	29	10
Female	39	10
Education		
Mainstream	16	16[1]
Unit	52	4
Type of amplification		
Cochlear Implant	43	_ _
Digital Aid	25	_ _

[1]Including 5 children in private schools

Table 2: Examples of spelling error categories taken from the BAS II (Elliott et al., 1996)

Error Category	Definitions	Examples from this study
No attempt	The participant makes no attempt to write the word.	N/A
Pre-Spelling	The participant writes a letter or series of letters but the assessor would be unable to decipher the word without checking the target spelling list.	C____ (quarrel) Upnet (obtain)
Major Non Phonetic	The misspelling shows limited visual and phonetic similarity to the target word. Errors may contain more letters than necessary or sounds are written with inappropriate letters.	Frieds (friend) Mornke (morning)
Non Phonetic Order Error	The letters required to spell the word are present but in the incorrect order.	Brid (bird) Brigde (bridge)
Semi Phonetic Error	The participant represents some of the phonetic information of the word in the correct order without inserting inappropriate graphemes.	Moring (morning) Ho (home)
Basic Phonetic Error	All the phonemes of the target word are represented in the correct order but the resulting word is not a homophone of the	Whail (while) Acation (occasion)

	target using regular phoneme – grapheme correspondence.	
Plausible Phonetic Alternative	The error is a homophone of the target word using regular phoneme – grapheme correspondence.	Allthough (although) Buss (bus)

Table 3: Literacy standard scores according to amplification type (deaf participants) and for the combined deaf group in comparison with the hearing dyslexic participants.

		Spelling		Word reading	
	n	*M*	*SD*	*M*	*SD*
Type of aid					
Cochlear implants	43	92.88	14.21	88.91	13.43
Digital aid	25	87.64	17.55	87.52	14.43
Combined groups					
Deaf (total)	68	90.96	15.6	88.4	13.72
Hearing dyslexic	20	89.30	9.6	92.85	12.37

Table 4: Distribution of spelling strategy as indicated by spelling error type

		Type of spelling errors		
Group	n	Mainly non-phonetic 0-40%	Mixed 41-59%	Mainly phonetic 60-100%
Deaf	68	21 (30.9%)	22 (32.4%)	25 (36.8%)
Hearing dyslexic	20	1 (5%)	1 (5%)	18 (90%)

Table 5: Descriptive and inferential statistics, including effect sizes for spelling and reading performance according to spelling error profile for the deaf group

Literacy Measure	Error type: Phonetic (n=25) M	SD	Mixed (n=22) M	SD	Non-phonetic (n=21) M	SD	F(2,65)	η^2
Spelling	97.84	15.24	91.23	15.84	82.48	11.76	6.44**	.17
Word reading	96.38	12.02	88.95	14.25	78.33	7.61	13.6***	.3

**p<.01; ***p<.001

Table 6: Correlations between PPE and performance on other scores.

	Variable					
	Spelling	Reading	Expressive Vocabulary	Nonverbal	Speech reading	Speech production
PPE						
Group						
Deaf	**.47*** **	**.59*** **	**.55*** **	**.23**[+]	**.19**	**.52*** **
Hearing dyslexic	.21	.47*	-.08	.23	-.11	- -

[+]Borderline significance (p=.06), * p<.05, ***p<.001

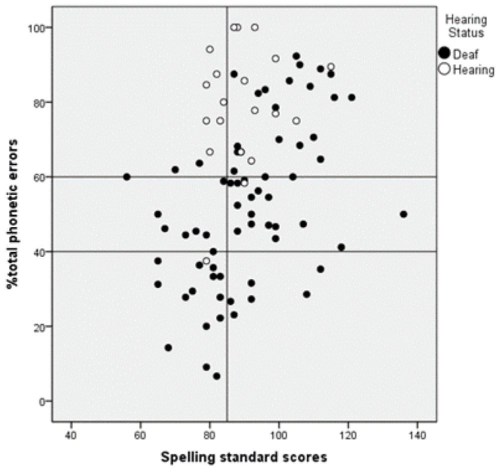
(Expressive vocabulary (EOWPVT): $Mean_{OD}$=79.88,SD_{OD}=16.07; $Mean_{HD}$=99.75,SD_{HD}=12.71;Speech reading (TOCS): $Mean_{OD}$=106.91,SD_{OD}=16.97; $n_{HD=15,}$ $Mean_{HD}$=87.4,SD_{HD}=12.27;Speech production (SIRS): $Mean_{OD}$=4.16,SD_{OD}=.96, minimum=1, maximum=5).

Table 7 Predictors of PPE in the deaf group

Predictor	B	SE	B	T	p value	R^2
Model 1 Constant	-5.88	11.21				
EOWPVT	.73	.14	.55***	5.28	<.001	29.7
Model 2Constant	18.97	11.72				
EOWPVT	.5	.16	.38**	3.19	.002	37.7
Speech intelligibility	7.31	2.58	.33**	2.83	.006	
Nonverbal	.01	.12	.01	.1	.92	

Figure 1: Scattergrams illustrating the relation between PPE and (A) children's spelling and (B) reading scores

A



B

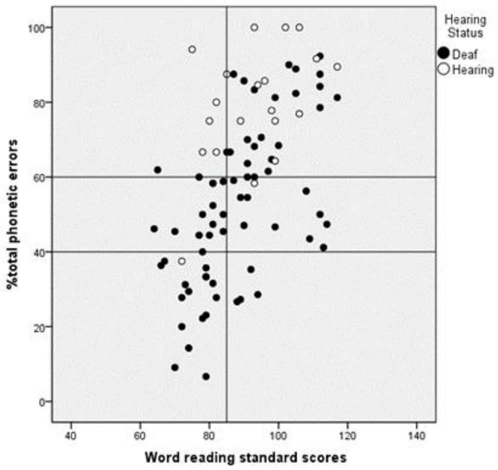


Figure 2: Scattergram showing the relation between PPE and expressive vocabulary according to speech intelligibility