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*Running head: Patterns of emerging literacy in deaf children*

**Longitudinal patterns of emerging literacy in beginning deaf and hearing  
readers**

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## **Abstract**

The emerging reading and spelling abilities of twenty-four deaf and twenty-three hearing beginning readers were followed over two years. The deaf children varied in their language backgrounds and preferred mode of communication. All children were given a range of literacy, cognitive and language-based tasks every twelve months. Deaf and hearing children made similar progress in literacy in the beginning stages of reading development and then their trajectories began to diverge. The longitudinal correlates of beginning reading in the deaf children were earlier vocabulary, letter sound knowledge and speechreading. Earlier phonological awareness was not a longitudinal correlate of reading ability, once earlier reading levels were controlled. Only letter name knowledge was longitudinally related to spelling ability. Speechreading was also a strong longitudinal correlate of reading and spelling in the hearing children. The findings suggested that deaf and hearing children utilise slightly different reading strategies over the first two years of schooling.

## **Introduction**

Deaf readers typically experience difficulties when faced with the complex task of learning to read a written language that is derived from a spoken language to which they do not have complete access. As a consequence, deaf children's reading ability is often severely delayed and they typically leave school without age appropriate reading skills (e.g. 1986; Conrad, 1979; DiFrancesca, 1972; Trybus & Karchmer, 1977; Wauters, van Bon, & Tellings, 2006). This can have long-term effects and consequences in terms of further education and employment opportunities. It is therefore imperative to determine which skills are important for beginning deaf readers and which skills measured at the beginning of the reading process indicate the ease and skill with which deaf children will acquire the alphabetic principle and achieve comparatively fluent reading.

We know from longitudinal research with typically developing hearing children that different skills play different roles in the reading process depending upon which stage of reading the child is at (e.g. Storch & Whitehurst, 2002; Wagner, et al., 1997). Phonological awareness and alphabetic skills i.e. letter knowledge, have been shown time and time again to be important for beginning reading and spelling in hearing children (e.g. Caravolas, Hulme, & Snowling, 2001; Lonigan, Burgess, & Anthony, 2000; Muter, Hulme, Snowling, & Stevenson, 2004; Wagner, et al., 1997). Phonological awareness refers to the ability to recognise, reflect upon and manipulate the constituent sounds within words; children who perform well on tasks that measure this ability typically make more progress in early word reading and spelling skills (see Castles & Coltheart, 2004; Goswami & Bryant, 1990). Gombert (1992) proposed that phonological awareness can be assessed at two distinct levels: epi-phonological

awareness and meta-phonological awareness. Epi-phonological awareness refers to an implicit awareness of, or sensitivity to, the constituent sounds in words. Typical tasks that measure epi-phonological awareness include syllable tapping (e.g. tap the number of syllables in *elephant*); rhyme judgement (e.g. do *blue* and *too* rhyme?) and oddity tasks (e.g. which word is the odd word out: *cat*, *bat*, *rag*?). Meta phonological awareness refers to a more explicit ability to manipulate and identify the constituent linguistic units in words such as a phoneme blending task (e.g. what word do /d/ /o/ and /g/ make?) or a phoneme deletion task (e.g. what is *play* without the /p/ sound?). Whilst both epi and meta-phonological awareness are usually assessed orally with hearing children, tasks specifically designed for deaf children typically measure epi-phonological awareness using a picture based format.

Although relatively fewer longitudinal studies have been conducted with deaf pre-readers or beginning readers, a number have focused on phonological skills (Colin, Magnan, Ecalle, & Leybaert, 2007; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008; Harris & Beech, 1998). Harris and Beech (1998) compared beginning deaf and hearing readers on a phonological similarity task in which children were required to indicate which of two pictures sounded similar to a target picture. The pictures either shared the beginning, middle or end sound with the target picture. Although the deaf children were significantly poorer on the phonological awareness task than the hearing children, their performance was associated with reading ability one year later (.43). It is important to note that the deaf children varied in their language backgrounds and in their preferred mode of communication, including both children educated orally and through sign supported English (SSE). Colin et al. (2007) assessed rhyme judgement and rhyme generation skills in a group of deaf pre-readers educated through Cued Speech. Cued Speech is a

method of communication in which lip patterns are disambiguated through a system of hand shapes that are placed in specific locations and with particular movements around the face (see Charlie & Leybaert, 2000 for more information). Colin et al. found that phonological skills measured in kindergarten were a significant predictor of the deaf children's reading ability in first grade, accounting for 28% of the variance in later reading scores, even after controlling for age and NVIQ. Easterbrooks et al. (2008) found that phonological skills measured at the beginning of a school year were associated with word reading ability at the end of the school year. They gave tasks measuring a broad range of phonological skills including rhyme, alliteration and syllable segmentation. The deaf children in their study were aged between 3 and 6 years old and had moderate through to profound hearing losses (>50 db). All participating children were able to perceive some speech through amplification of residual hearing or a cochlear implant.

The role of other cognitive and language skills in deaf children's emerging literacy has received comparatively little attention. In addition to phonological skills, Easterbrooks et al. (2008) found that both expressive vocabulary (.52) and letter sound knowledge (.63) were correlated with reading ability 9 months later in their cohort of young deaf and hard of hearing children. For the beginning readers in the Harris and Beech (1998) study earlier language comprehension (.37) and speech intelligibility (.57) were both significantly associated with reading progress. Similarly, Spencer and Oleson (2008) found that speech skills were longitudinally related to reading ability in slightly older deaf children with cochlear implants. After four years of implant experience, speech production and speech perception skills, assessed when the children were on average 7 year 6 months, were the strongest longitudinal predictors of subsequent reading four years later.



A recent longitudinal study with slightly older deaf children (Kyle & Harris, 2010) found that vocabulary knowledge and speechreading skills were longitudinally predictive of later reading achievement and reading growth. The study followed a cohort of deaf children (7- and 8-year-olds) from mixed language backgrounds, over a period of three years. Those deaf children with better speechreading and vocabulary skills at age 7 made more progress in reading ability by age 11. There was an intricate pattern of relationships between phonological awareness, speechreading and reading. Speechreading was a strong predictor of initial word reading skills whereas phonological awareness only became concurrently associated with reading at the end of the study, i.e., once the underlying phonological representations, mediated by speechreading, had developed enough to support phonological awareness and reading. Kyle and Harris's findings were consistent with the argument that speechreading provides the primary input for phonological representations in deaf children (e.g. Burden & Campbell, 1994; Dodd, 1980; Leybaert & Alegria, 1995). Another possible interpretation of the results was that speechreading of single words might act as a marker of the quality of phonological representations during the early years (Kyle & Harris, 2010). In the current study we wanted to investigate whether speechreading and vocabulary play a role in deaf children's emerging literacy and also explore whether speechreading might equally be related to reading development in hearing children.

Kyle and Harris (2010) also reported that earlier phonological awareness was not a significant longitudinal predictor of later reading once the effects of earlier reading ability were controlled. Moreover, they found that earlier reading skills significantly predicted later phonological awareness, consistent with the theory that deaf children's phonological skills develop as a consequence of learning to read rather

than being a precursor of literacy (see Goldin-Meadow & Mayberry, 2001; Musselman, 2000). The discrepancy between the Kyle and Harris (2010) findings and those of Colin et al., Easterbrooks et al., and Harris and Beech most probably arises because it was only the first of these that controlled for earlier reading levels in the analyses. The deaf children in the Harris and Beech (1998) study could identify up to 4 words and one child could read 8 words; therefore, although these deaf children were very much beginning readers, they were able to read a few words, even if they were using a whole word strategy. Likewise, although Colin et al. (2007) do not mention the deaf children's kindergarten reading skills, it is probable that they may have been able to read at least a few words as their ages ranged from 5 years 5 months to 7 years 3 months. Therefore it is possible that in both Colin et al., and Harris and Beech's studies, the relationship between phonological awareness and reading might have been mediated by pre-existing literacy skills, regardless of their paucity (see Castles & Coltheart, 2004). In the present study, we explored this issue further by controlling for earlier levels of reading ability whilst investigating the relation between phonological awareness and reading in beginning deaf readers. We expected that once we controlled for the autoregressive effect of reading, there would no longer be a predictive relationship between earlier phonological awareness and later reading ability. However, we also thought it was possible that we might find that a relationship between earlier reading and later phonological awareness whereby phonological skills were influenced by early reading skills and pre-reading skills such as alphabetic knowledge. Alternately, we might observe findings consistent with Harris and Beech and Colin et al., indicating a developmental pattern whereby phonological awareness at age five does predict reading ability in deaf children aged seven.

The present study was also concerned with spelling. The literature on deaf children's spelling development is even sparser than that for reading and most studies have been cross-sectional. The main finding has been that deaf children's spelling ability is not as severely affected by their hearing loss as their reading ability (e.g. Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Burden & Campbell, 1994; Gates & Chase, 1926; Geers & Moog, 1989; Harris & Moreno, 2004). For example, Geers and Moog (1989) found that whilst only 30% of a group of deaf 16 year olds were reading age appropriately, 64% of them were spelling age appropriately. Likewise, Moores and Sweet (1990) reported that a group of deaf 16-17 year olds had a mean reading comprehension age of between 11 and 12 years but a mean spelling age of between 13 and 14 years. Other studies have observed higher levels of spelling ability in deaf children than would be predicted from their reading ability (Burden & Campbell, 1994; Harris & Moreno, 2004). Similar skills are usually found to be important for emerging reading and spelling abilities in hearing children (e.g. Caravolas, et al., 2001; Ellis & Large, 1988; Juel, Griffith, & Gough, 1986); however, a recent study reported a disparity in the concurrent predictors of reading and spelling in 7-year-old deaf children (Kyle & Harris, 2006). The present study therefore examined whether such a discrepancy is exhibited in the longitudinal predictors of emerging reading and spelling skills in deaf children.

Another strong longitudinal predictor of early reading and spelling ability in hearing children is knowledge of letter names and letter sounds (e.g. Caravolas, et al., 2001; Lonigan, et al., 2000; Muter, Hulme, Snowling, & Taylor, 1998). The Easterbrooks et al. (2008) study found that knowledge of letter-sound correspondences was related to reading in young deaf and hard of hearing children with some speech perception abilities. Mayer (2007) argues that the development of

emerging literacy is a similar process for deaf and hearing children; a corollary of this assumption is that deaf children would essentially require the same skills to access written English. Given the importance of alphabetic knowledge for hearing children, it is imperative to determine levels of letter name and letter sound knowledge in beginning deaf children, even those from mixed language backgrounds, and investigate whether this knowledge is actually predictive of emerging reading and spelling skills. Similarly, fairly strong relationships have also been observed between short-term memory span and reading development in hearing children (e.g. Ellis & Large, 1988; Swanson & Howell, 2001) and older deaf children (e.g. Daneman, Nemeth, Stainton, & Huelsmann, 1995; Harris & Moreno, 2004). Several studies have found slightly older deaf children's memory spans to be commensurate with those of younger reading age-matched hearing children (e.g. Harris & Moreno, 2004; Kyle & Harris, 2006); therefore it was of interest to examine whether beginning deaf readers had poorer memory spans than beginning hearing readers, and whether their short-term memory is related to reading.

In the present study, we investigate some of the outstanding issues described above by comparing emerging reading and spelling skills in deaf and hearing readers and examining the roles of various cognitive and language tasks in predicting their literacy development. The main aims of the current study were to (1) compare beginning deaf and hearing readers on a range of cognitive and language tasks thought to be related to reading and spelling; (2) determine the concurrent correlates of reading and spelling in beginning deaf and hearing readers; (3) compare deaf and hearing children's initial reading and spelling progress; (4) explore the longitudinal relations between earlier cognitive and language skills and later reading and spelling ability in beginning deaf readers, in particular whether earlier vocabulary and

speechreading skills are related to later literacy; (5) compare the longitudinal correlates of beginning reading in deaf children with those for hearing children; (6) clarify whether phonological awareness is related to later reading ability in beginning deaf readers after controlling for initial reading levels.

## **Methodology**

### ***Design***

A two-year longitudinal, comparative study was conducted with deaf and hearing children. Children were given a battery of reading, spelling, language and cognitive tasks every twelve months over the two year period. The data were collected between 2003 and 2005.

### ***Participants***

24 deaf and 23 hearing children aged between 5- and 6-years-old participated in the study. Schools and teachers were asked to select children who were beginning readers to take part in the study. As a result of this sampling method, most of the deaf children were either in their first year of schooling (i.e. kindergarten) or they were in the first term of their second year of school (i.e. 1<sup>st</sup> grade) but were considered to be beginning readers by their class teacher. To ensure that the hearing children were also beginning readers, they were recruited from kindergarten classes. This resulted in some of the deaf children being older than the hearing children (mean age at the beginning of the study 5 years 8 months vs. 5 years 0 months),  $t(30) = 8.28, p < .001$ , 95% CI 6.48 – 10.72.

The deaf and hearing children were matched for initial word recognition ability using a pictorially adapted version of the Primary Reading Test (France, 1981),

similar to the adaptation used in Harris and Beech (1998). The children were shown flashcards each containing a picture and 5 words and they had to point to the word that correctly corresponded to each picture. The sixteen pictures were the first 16 picture items from the Primary Reading Test. No standardised scores were computed due to the adapted presentation format of the test. There were four practise items on which the children could receive feedback. There were no significant differences between the deaf and hearing children in their word recognition abilities,  $t(45) = 0.53$ , ns, 95% CI -1.77 – 3.02,  $d = 0.14$ .

The children's non-verbal intelligence quotients (NVIQ) were estimated using three subtests from the British Ability Scales II (BAS II) (Elliot, Smith, & McCulloch, 1996): Pattern construction, Block Building and Copying. All participating children had a NVIQ estimate greater than 85. There were no significant differences between the deaf and hearing children in their NVIQ,  $t(45) = -1.74$ , ns, 95% CI -7.75 – 0.57, or gender distribution  $\chi^2(1) = 0.51$ , ns. Any child with cognitive, social or severe behavioural problems was excluded from the study at the beginning. There were an additional eight deaf children who had been initially assessed but then excluded before the onset of the study due to low cognitive abilities and suspected attentional difficulties.

### *Deaf participants*

The deaf children's mean chronological age was 5 years 8 months (SD 4.7) at the initial assessment and ranged from 4 years 11 months to 6 years 5 months. There were 9 boys and 15 girls. All children had a severe or profound sensori-neural pre-lingual hearing loss with a mean loss of 100 db (across 4 frequencies in the better ear), ranging from 76db to >120db. The children came from a range of different schools

and educational establishments in the south east of England including specialist schools for the deaf and hearing-impaired units attached to mainstream schools. Seven children were fitted with cochlear implants and the remaining 17 wore digital hearing aids. The mean age of implantation for the children with cochlear implants was 3 years 5 months (SD 17.6) and ranged from 2 years to 5 years 8 months. Five children had at least one deaf parent and a further 2 children had a deaf sibling. The language and communication backgrounds of the children varied tremendously: 11 preferred to communicate through only spoken English, 10 used signing (8 of whom used BSL) and 3 children used total communication (a combination of spoken and signed language).

#### *Hearing participants*

23 typically developing hearing children took part (11 boys and 12 girls). The mean age was 5 years 0 months (SD 1.8) and ranged from 4 years 8 months to 5 years 2 months. The hearing children were all pupils at the mainstream schools to which the deaf units were attached, ensuring the deaf and hearing children were matched for socioeconomic status and demographic variables. Spoken English was the first language of all hearing children.

#### ***Materials***

A broad battery of reading, spelling, cognitive and language based tasks was administered at Time 1, Time 2 and Time 3.

*Word reading* ability was assessed using the Single Word Reading subtest from the BAS II (Elliot, et al., 1996). The children were shown an A4 card containing printed

words of increasing difficulty and asked to read them aloud. The deaf children were allowed to respond in their preferred communication method: spoken English, signing or total communication (a combination of signed and spoken English). The maximum score for the word reading task was 90.

*Spelling ability* was measured by an experimental picture-to-spelling task (from Kyle & Harris, 2006). The children were shown 30 black and white line drawings (taken from Snodgrass & Vanderwart, 1980), depicting concrete nouns of varying syllabic length (e.g. cat, door, carrot and aeroplane). The target monosyllabic words also varied in their phonology-to-spelling regularity and consistency. A word was categorized as being regular if there was only one, or a principal, method of graphemically representing the constituent sounds (see Ziegler, Stone, & Jacobs, 1997). The words were selected from spelling lists used in two previous studies with deaf children ((Burden & Campbell, 1994; Harris & Moreno, 2004). The words depicted were all characterized as being of high frequency (see norms from Masterson, Stuart, Dixon, & Lovejoy, 2003) and early age of acquisition (see norms from Morrison, Chappell, & Ellis, 1997). Using hearing norms, the mean age of acquisition for the included items was 26 months and therefore it was expected that the items would be familiar to typically developing 5 year old deaf children, despite their well-documented language delays. The pilot study revealed that the chosen items were suitable as they were found to be in the vocabularies of deaf children of the target age. The items were presented one at a time and named (and additionally signed for those children who used sign language) to ensure clarity. Children were asked to write down the name of each item. Cronbach's alpha reliability coefficient was .90. The maximum score was 30.



*Phonological Awareness* was assessed using the phonological similarity task taken from Kyle and Harris (2006; 2010). This task measured epi-phonological awareness and was included because it had been used in previous studies with deaf children (e.g. Colin, et al., 2007; Harris & Beech, 1998; Kyle & Harris, 2006, 2010; Miller, 1997). Children were required to make a judgement of either rhyme or alliteration similarity. There were 24 trials in which the child was presented with a picture (item) and then shown 2 further pictures (a target and distractor) of which they had to select the picture that sounded the same as the item. On 12 of the trials, the item and target shared the same onset and thus required a judgement of alliteration similarity (e.g. *bat bag man*). On the remaining 12 trials, the item and target shared the same rime and required a judgement of rhyme similarity (e.g. *key tree flag*). The orthographic congruency was controlled on the 12 rhyme trials, whereby on 6 of the trials, the item and target shared the same spelling (e.g. snake-cake) but on the other 6 trials, the item and target had different spellings (e.g. eye-fly). A more detailed description of the task is provided in Kyle and Harris (2006, 2010). Children were pre-tested on all the pictures to ensure they knew the correct labels for the pictures. There were also four additional practice trials in which the children could receive feedback. Cronbach's alpha reliability coefficient was .66. The maximum score for this task was 24.

*Productive Vocabulary* was assessed through the Productive vocabulary subtest from the BAS II (Elliot, et al., 1996). Children were shown 36 pictures and asked to produce the name of the picture. They were allowed to answer in sign, speech or fingerspelling. When scoring the signed answers, we used similar guidelines to

Connor and Zwolan (2004) whereby any response that was a sign rather than a description or gesture was accepted.

*Speechreading* ability was measured using the video-to-picture matching speechreading task taken from Kyle and Harris (2006; 2010). The children watched a series of video clips of a woman saying a word and after each video clip they had to point to the corresponding picture from a picture board. The video clips were recorded audio-visually but presented silently to the children on a laptop. There were five different picture boards, each requiring different contrasts, and 10 trials on each board. The items on board 1 were of varying syllabic length (e.g. *fish*, *apple*, *butterfly*) whereas the items on board 2 were all disyllabic words (e.g. *pencil*, *flower*, *carrot*). The items on board 3 were all monosyllabic words that began with the sound /b/ (e.g. *box*, *bus*, *bike*). Boards 4 and 5 both contained monosyllabic words that rhymed (e.g. *bear*, *fair*, *pear* and *key*, *bee*, *tree* respectively). The items were all named on each board before the task commenced. The order of presentation of the boards was counterbalanced. Cronbach's alpha reliability coefficient was .91. The maximum score was 50.

*Short-term memory span* was assessed using a pictorial, serial ordered, short-term memory task taken from Kyle and Harris (2006; 2010). The children were presented with sets of pictures on a computer screen and they had to recall the pictures in the correct order. The task began with lists of two pictures and increased up to a maximum of six pictures. Three trials were presented at each list length and the test was stopped when the child made errors on at least two trials at a given list length. The task was comprised of two sections, one providing a span for monosyllabic words

(e.g. *bike, fox, tent, lips*) and the other providing a span for disyllabic words (e.g. *apple, flower, rabbit, button*). The words were matched across the two sections in terms of word frequency (see norms from Masterson, et al., 2003) and the age at which the words are typically acquired (see norms from Morrison, et al., 1997). The items in each section were also dissimilar in terms of phonological, visual or sign properties. The words were depicted by black and white line drawings taken from Snodgrass and Vanderwart (1980) database. Children were pre-tested on the pictures before the task began and there were three practice trials at the beginning of each section. The order in which the two sections were presented was counterbalanced. Children were allowed to respond in their preferred language. The maximum score was 6.

*Letter Name and Letter Sound Knowledge* was measured by asking children to produce the names and sounds for each of the 26 letters of the English alphabet. Children were presented with 26 brightly colored, magnetic, alphabetic letters on a magnetic board. They were shown each letter in turn and asked to give the name of the letter and the corresponding sound made by that letter. Children were allowed to provide the name of the letter using speech or fingerspelling. They were then asked what sound the letter made. The task was introduced by initially showing children the letter that their own name began with and asking them to name it. Almost all the participating children were receiving speech and language therapy sessions at school through which the concept of sounds was being taught and further instructions and help was given when necessary. Children scored one point for each correct name or sound. The maximum score for letter name knowledge was 26 and the maximum score for letter sound knowledge was 26.

### ***Procedure***

A small pilot study was conducted with 3 deaf children to ensure that the tasks, instructions and procedures were appropriate for beginning readers. Any instructions that were not clear were amended and advice was sought from teachers of the deaf. Parental and child permission was given prior to initial assessment. All testing took place in a separate room, usually adjacent or close by the classroom. Each child was assessed every twelve months. Six sessions were required each year to complete the testing battery and each session lasted for approximately 20 minutes. For the deaf children, all instructions were given in the child's preferred mode of communication: spoken English, total communication or signing.

### **Results**

The means and standard deviations for all literacy, cognitive and language tasks at all three testing periods for both the deaf and hearing children are presented in Table 1.

#### ***Performance on the reading and spelling tasks at Time 1***

The deaf and hearing children had initially been selected and matched for word recognition skills at T1. However, despite being matched for reading ability on a measure of word recognition, the deaf children achieved significantly higher scores than the hearing children on the test of single word reading ( $t(27) = 2.39$ ,  $p = .024$ , 95% CI 0.66 – 8.61,  $d = 0.68$ ). The mean reading age for the deaf children was 5 years and 3 months whereas the mean reading age for the hearing children was 5 years 0 months. The deaf children also attained higher spelling scores than the hearing children ( $t(28) = 2.33$ ,  $p = .028$ , 95% CI -0.22 – 3.40,  $d = 0.67$ ). The differences

between the deaf and hearing children in word reading and spelling arose because all the hearing children were in their first year of school whereas, although the majority of deaf children were also in their first year of school and were beginning readers, a few of them were in the first term of their second year of school (i.e. first grade) and therefore could read and spell a couple of words even though their teachers had selected them as being beginning readers.

<Table 1 about here>

### ***Performance on the cognitive and language based tasks at Time 1***

As can be seen in Table 1, the hearing children achieved higher scores on the phonological awareness ( $t(43) = -2.68$ ,  $p = .010$ , 95% CI  $-4.79 - -0.68$ ,  $d = 0.80$ ), letter sound knowledge ( $t(35) = -3.39$ ,  $p = .002$ , 95% CI  $-10.7 - -2.7$ ) and the productive vocabulary task ( $t(45) = -6.71$ ,  $p < .001$ , 95% CI  $-11.97 - -6.44$ ,  $d = 1.96$ ). As expected, the hearing children had age-appropriate vocabulary skills whereas the deaf children showed considerable delays (mean vocabulary age = 2 years 11 months). The deaf children knew significantly more letter names than the hearing children ( $t(45) = 3.64$ ,  $p = .001$ , 95% CI  $-3.9 - 13.4$ ).

There were no significant differences between the deaf and hearing children in their speechreading skills,  $F(1,45) = 2.25$ , ns. There was also a main effect of board,  $F(4,180) = 11.34$ ,  $p < .001$  but no significant interaction,  $F(4,180) = 0.84$ , ns. Post-hoc analysis revealed that deaf and hearing children showed a similar pattern of performance across the different boards. There were also no differences between the deaf and hearing children in their performance on the short-term memory span task,  $t(45) = -1.07$ , ns, 95% CI  $-0.38 - 0.12$ ,  $d = 0.26$ .

### ***Concurrent relations between literacy and cognitive and language tasks at Time 1***

Table 2 shows the concurrent partial correlations (controlling for NVIQ) between the tasks at T1 for the deaf children. Both reading and spelling ability were significantly associated with phonological awareness and vocabulary. In addition, reading ability was significantly correlated with speechreading. Reading and spelling were themselves highly inter-correlated as were speechreading and phonological awareness.

Table 3 shows the concurrent partial correlations for the hearing children, controlling for NVIQ. Apart from reading and spelling themselves being highly inter-correlated, the only significant correlate of reading and spelling ability was letter sound knowledge. In addition, letter name knowledge was significantly associated with spelling ability. It must be remembered that the hearing children were beginning readers and spellers and so the lack of significant correlates after controlling for NVIQ is most probably due to floor effects in the literacy tasks.

<Table 2 about here>

<Table 3 about here>

### ***Development of reading and spelling skills over the two years***

A two-way ANOVA (group by time) revealed that significant progress was made between each successive year in reading ability as there was a main effect of testing time on the reading scores,  $F(2,88) = 226.65$ ,  $p < .001$ . There was no main effect of group,  $F(1,44) = 0.06$ , ns but there was a significant interaction,  $F(2,88) = 16.12$ ,  $p < .001$ . Post-hoc analysis revealed that deaf and hearing made similar progress between T1 and T2 but the hearing children made greater progress between T2 and T3 than the deaf children. A second two-way ANOVA (group by time) was computed

for the spelling scores and revealed that significant progress was also made between each year in spelling ability. There was a main effect of testing time on the spelling scores,  $F(2,88) = 280.64, p < .001$  but there was no main effect of group,  $F(1,44) = 0.26, ns$ . There was a significant interaction,  $F(2,88) = 4.87, p = .010$  and post-hoc analysis revealed that at T1 the deaf children had achieved higher spelling scores than the hearing.

***Longitudinal relations between earlier cognitive and language abilities and later reading and spelling achievements***

The longitudinal relations between earlier cognitive and language skills and later reading and spelling abilities were investigated through cross-lagged partial correlations. Cross-lagged correlations help identify the causal direction of a relationship between two variables by comparing the strength of the correlation in each direction (see Ellis & Large, 1988; Kenny, 1975). NVIQ and earlier levels of literacy ability were always entered as covariates in the cross-lagged correlations; this provided a stringent and conservative method of investigating the influence of possible predictor variables on later literacy scores after controlling for any earlier influence of reading or spelling on those predictor variables (see Castles & Coltheart, 2004). This also controlled for the autoregressive effect of literacy, whereby the strongest predictor of later reading and spelling abilities is typically earlier reading or spelling achievement (see Caravolas, et al., 2001).

***Cross-lagged partial correlations for deaf children***

The cross-lagged partial correlations for the deaf children are displayed in Table 4. Vocabulary at T1 was the most consistent significant correlate of reading ability at T2

and T3, even after controlling for NVIQ and earlier reading ability at T1. The converse relation between earlier reading ability and later vocabulary was not significant. Both speechreading at T1 and letter sound knowledge were significantly related to reading ability at T3. These represent medium to large effects of earlier vocabulary, speechreading and letter sound knowledge on later reading. Phonological awareness at T1 was not significantly related to reading ability at T2 or T3; however, there was a significant association between reading ability at T1 and phonological awareness at T2 (large effect), even after controlling for NVIQ and phonological awareness scores at T1. In contrast to the longitudinal correlates of reading, only letter name knowledge was significantly associated with spelling ability both at T2 and T3. Spelling ability at T1 showed a significant negative relation with speechreading performance at T3, whereby the better the spelling at T1, the less progress was made in speechreading scores by T3.

<Table 4 about here>

#### *Cross lagged partial correlations for hearing children*

The cross-lagged partial correlations for the hearing children are displayed in Table 5. For the hearing children, speechreading at T1 was the most consistent longitudinal correlate of later reading ability at T2 and T3, even after controlling for reading ability at T1 and NVIQ. Speechreading and phonological awareness at T1 were the most consistent predictors of spelling ability at T2 and T3, after controlling for spelling ability at T1 and NVIQ. In addition, letter name knowledge at T1 was a significant correlate of reading at T2 and phonological awareness at T1 was a significant correlate of reading at T3. Furthermore, vocabulary at T1 was significantly related to spelling ability at T2. Therefore, for the hearing children, a similar pattern of cross-



lagged partial correlations between T1 and T3 was observed for spelling and reading ability. Moreover, the converse relations between reading and spelling ability at T1 and later language and cognitive skills at T2 or T3 were not significant.

<Table 5 about here>

### ***Effects of mode of communication on literacy and cognitive and language tasks***

As the deaf children came from a range of language backgrounds and communication preferences, it was possible that significant within-group differences were hidden as a result of combining the children into one group. In order to investigate this further, the children were split into two subgroups based upon their preferred communication mode: (1) those who used speech when communicating (n=14) and (2) those who preferred to use signing (n=10). At Time 1, there were no statistically significant differences between these two groups on any of the literacy, cognitive or language tasks. The concurrent partial correlations at T1 for both the speech and the signing group showed an almost identical pattern of associations to those reported in Tables 2 and 3. At Time 3, there was only one significant difference between the groups: the oral group had better letter sound knowledge than the signing group (mean 14.6 vs. 3.5;  $t(22)=3.60$ ,  $p<.001$ ). The groups did not differ on any of the other skills that predicted reading and spelling ability. Caution should be applied when interpreting the above results as there is a lack of statistical power due to the small sample size of each subgroup. The lack of statistical power also precluded separate cross-lagged partial correlations being computed for each group.

## **Discussion**

Despite the deaf and hearing children exhibiting very similar levels of reading progress in the early stages of reading development, their reading trajectories began to diverge after the second year of reading instruction. Therefore, although the reading delay in beginning deaf readers was not as serious as that typically observed with older deaf children, the results were supportive of the notion that the severity of the delays increase with age (e.g. Allen, 1986; Easterbrooks, et al., 2008; Trezek, Wang, Woods, Gampp, & Paul, 2007).

Unsurprisingly, beginning deaf readers had weaker phonological skills (Colin, et al., 2007; Harris & Beech, 1998) and letter sound knowledge than beginning hearing readers, although they had higher levels of letter name knowledge. They exhibited a similar pattern of strengths and weaknesses on the other literacy-related skills compared with slightly older deaf children, such as poorer vocabulary knowledge yet equivalent short-term memory spans and speechreading skills (see Kyle & Harris, 2006). Phonological awareness was a strong concurrent correlate of literacy skills in the deaf children at T1 (Campbell & Wright, 1988; Dyer, MacSweeney, Szczerbinski, & Green, 2003; Easterbrooks, et al., 2008). However, reading ability also showed significant positive concurrent associations with almost all of the other cognitive and language tasks at T1, suggesting that the beginning deaf readers were potentially drawing upon all their available skills and knowledge rather than utilising a specific reading strategy. It was difficult to compare the deaf and hearing children's concurrent correlates as the hearing children's lack of correlates were most likely due to floor effects on the literacy measures at T1.

The most important finding from this study concerned the longitudinal predictors of deaf children's early reading progress. Earlier vocabulary, speechreading and letter sound knowledge measured at age 5 correlated with the

individual differences seen in reading ability two years later at age 7. Notably, these associations held even after statistically controlling for levels of hearing loss, NVIQ and earlier ability. The skills longitudinally associated with reading progress in beginning deaf readers were therefore very similar to the longitudinal predictors of reading growth in slightly older deaf children (Kyle & Harris, 2010) , with the addition of letter sound knowledge (Easterbrooks, et al., 2008). Interestingly, in the current study, earlier vocabulary was the most consistent correlate of later reading across the study whereas earlier speechreading was only a significant correlate of later reading ability at age 7. This finding could be indicative of the type of reading strategy that the deaf children were using; it suggests that speechreading only accounts for individual differences in reading skill once a sufficient level of literacy has been achieved to enable use of a reading strategy based upon phonological representations, derived through speechreading. Further support for this view comes from the high correlation between earlier speechreading and later phonological awareness (.79) which strongly suggests that speechreading provides the input for underlying phonological representations.

There is also evidence in our data that speechreading is important for beginning hearing readers. Rather to our surprise, speechreading proved to be a strong and consistent longitudinal correlate of both reading and spelling development in the hearing children. A logical explanation for this strong association is that hearing children also incorporate the information derived through speechreading into their phonological representations. Given that speechreading is a natural part of speech perception in face to face communication (e.g. Massaro, 1987; Summerfield, 1987), it is likely that even hearing children's phonological representations will include some information about the visual component of speech sounds. Better speechreading skills

may therefore result in more distinct and specified phonological representations, which in turn can help typically developing hearing children when learning to read and spell. The strong associations observed between their speechreading and phonological awareness skills both concurrently at T1 and longitudinally between T1 and T3 (.58) further support this argument. Unsurprisingly, phonological awareness and letter name knowledge were also strong correlates of emerging literacy in the hearing children (e.g. Lonigan, et al., 2000; Muter, et al., 2004).

The third main finding from the current study was that, once the effects of earlier reading ability were controlled for, phonological awareness was not longitudinally predictive of later reading ability in beginning deaf readers. However, prior to controlling for earlier reading, phonological awareness at T1 had indeed been associated with later reading both at T2 (.58) and T3 (.64). This suggests that, as hypothesised in the Introduction, the relations observed between earlier phonological awareness and reading ability in the Harris and Beech (1998) and Colin et al. (2007) studies might have been mediated by existing reading skills. Furthermore, the strong relation found between earlier reading ability at T1 and later phonological awareness at T2, could be taken as evidence in support of the theory that deaf children might develop their phonological skills through learning to read rather than phonological skills being a pre-requisite of literacy (see Goldin-Meadow & Mayberry, 2001; Kyle & Harris, in press; Musselman, 2000).

However, an alternate explanation for the observed correlation between earlier reading and later phonological awareness is that the acquisition of reading skills influences the way in which children complete phonological awareness tasks by enabling them to make use of orthographic information (see Castles & Coltheart, 2004). At Time 1, the deaf children did not appear to be using orthographic

information to complete the task as there was no difference between their performance on items that were phonologically and orthographically congruent or phonologically and orthographically incongruent ( $t(23) = .20$ , ns). However, by Time 3, the deaf children showed the typical pattern of performance reported in previous studies (e.g. Campbell & Wright, 1988; Kyle & Harris, 2006) whereby they scored higher on the orthographically congruent items that could be completed using orthographic information ( $t(23) = 3.31$ ,  $p = .003$ ). Whilst this appears to support the Castles and Coltheart (2004) interpretation of the association between earlier reading and later phonological awareness, it should be noted that the improvement in performance on the phonological awareness task between T1 and T3 was not solely limited to the orthographically congruent items as the deaf children also showed improvement on the incongruent items indicating enhanced phonological awareness. Therefore, from the current study it is difficult to draw definite conclusions over whether the deaf children were using phonological or orthographic information to complete the task. Moreover, as the main aim of the current study was to investigate the role of a range of cognitive and language based tasks in deaf children's reading development, only one measure of phonological awareness was included. Future research aiming to explore the complex role of phonological awareness in deaf children's reading should include a range of epi- and meta-phonological awareness and compare the predictability of each task once pre-existing literacy skills have been controlled.

It was also of interest that the longitudinal correlates of early spelling development in deaf children showed a slightly different pattern to those observed for early reading development. In contrast with reading ability, no significant relation was observed between earlier speechreading, letter sound knowledge or vocabulary

and later spelling; the only significant association was between early letter name knowledge and later spelling outcomes. This apparent disparity in the cognitive predictors of beginning reading and spelling in deaf children was similar to that reported concurrently for 7 year old deaf children (see Kyle & Harris, 2006) but was not observed with the hearing children in the study, consistent with previous research (e.g. Caravolas, et al., 2001; Ellis & Large, 1988; Juel, et al., 1986). The results suggested that a different developmental pattern may be emerging with deaf children's spelling which therefore warrants further research to determine the skills underpinning spelling development for deaf children. It should be noted that the use of an experimental rather than standardized spelling task might have precluded the detection of significant correlates in the current study. In addition, the dichotomous scoring procedure (correct or incorrect) did not take into account how phonologically plausible the deaf children's spelling errors were. Future research should take phonological plausibility into account when investigating the predictors of spelling in deaf children.

Research suggests that different subgroups of deaf children may take slightly different pathways to literacy (e.g. Harris & Beech, 1998; Miller, 1997), utilising skills in signing (see Hoffmeister, 2000; Strong & Prinz, 2000) or fingerspelling (see Haptonstall-Nykaza & Schick, 2007; Padden, 1991; Padden & Ramsey, 2000). Whilst the current study included deaf children from varied language backgrounds and communication preferences, the sample size precluded a thorough investigation of potential differences in predictors of reading development as a result of this variation. The strongest evidence for phonological skills in deaf children comes from subgroups who are "more oral" (e.g. Charlier & Leybaert, 2000; Miller, 1997), and thus it would be reasonable to suggest that speechreading might only be predictive of reading

ability in oral deaf children rather than in signers (see Arnold & Kopsel, 1996). However, the findings of two recent studies (Harris & Moreno, 2006; Kyle & Harris, 2010), in which good deaf readers exhibited superior speechreading skills regardless of their communication preferences, suggest that the role of speechreading in deaf children's reading may not be just limited to oral deaf children. Moreover, in the current study, it should be remembered the oral and signing deaf subgroups did not differ in speechreading or phonological awareness skills at both Time 1 and Time 3.

A related issue is whether speechreading could simply be a proxy for oral skills. Spencer and Oleson (2008) found speech production and speech perception skills were the strongest predictors of reading development in deaf children with cochlear implants; silent speechreading, as measured in the current study, is essentially visual-alone speech perception. However, given that good speechreading skills are found in both oral and signing deaf children (see above discussion), and that in the Harris and Moreno (2006) study, speechreading was found to be independent of speech production as the good and poor readers in their study differed on speechreading but not on speech intelligibility, it is unlikely that speechreading is simply a measure of, or proxy for, oral abilities.

A final issue for consideration is that the deaf and hearing children in the current study did not end up being as closely matched as originally intended. The children were selected as being beginning readers by their class teachers, and as a result, the deaf children were older. Therefore, although the groups were matched for reading ability using a reading test measuring word recognition, it transpired that there was a difference in their ability at the level of word reading, with the deaf children achieving higher scores. Whilst these group differences are large enough that they

should be acknowledged they are not large enough that they should detract from the findings concerning the predictors of reading ability.

What do these results tell us about reading development in beginning deaf readers? Taken together, the findings suggest that deaf children are utilising different reading strategies at different stages whereas hearing children are using a more consistent strategy. In the beginning stages of reading development, the deaf children appeared to be using a logographic or whole word strategy as vocabulary was the only significant predictor of initial reading progress. However, after two years of reading instruction, reading ability was also predicted by earlier speechreading skills and letter sound knowledge, suggesting that deaf children were then using a more alphabetic reading strategy that tapped into underlying phonological representations derived, at least in part, from speechread input. In contrast, the hearing children appeared to be using a more alphabetic strategy right from the first year of reading development as speechreading and then phonological awareness were strong predictors of both reading and spelling growth.

If the information derived through speechreading is incorporated into underlying phonological representations, which in turn are used to support the phonological judgements required to complete phonological awareness tasks, then it is plausible that speechreading could be a strong initial predictor of reading in both deaf and hearing. In addition, for the deaf children, speechreading could essentially act as a marker or proxy for the quality of the underlying phonological representations. The findings in the current study provide further support for the argument proposed in Kyle and Harris (2010) that the relationship between reading and phonological skills in deaf children is mediated by speechreading until the underlying phonological representations themselves are strong enough to support reading.



In conclusion, the current study found that vocabulary, speechreading and letter sound knowledge were longitudinal predictors of beginning reading ability in deaf children from varied language backgrounds and communication preferences, including BSL users. Speechreading was also found to be longitudinally correlated with emerging reading and spelling abilities in typically developing hearing children. The pattern of observed correlates for deaf and hearing children suggests that these two groups might utilise slightly different reading strategies over the first two years of schooling.

## References

- Aaron, P. G., Keetay, V., Boyd, M., Palmatier, S., & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal*, 10, 1-22. doi: 10.1023/A:1007917929226
- Allen, T. E. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. N. Schildroth & M. A. Karchmer (Eds.), *Deaf children in America* (pp. 161- 206). San Diego, CA: College-Hill Press.
- Arnold, P., & Kopsel, A. (1996). Lipreading, reading and memory of hearing and hearing-impaired children. *Scandinavian Journal of Audiology*, 25(1), 13 - 20. doi: 10.3109/01050399609047550
- Burden, V., & Campbell, R. (1994). The development of word-coding skills in the born deaf: An experimental study of deaf school leavers. *British Journal of Developmental Psychology*, 12, 331-349.
- Campbell, R., & Wright, H. (1988). Deafness, spelling and rhyme: How Spelling supports Written Word and Picture Rhyming Skills in Deaf Subjects. *The Quarterly Journal of Experimental Psychology*, 40A(4), 771-788. doi: 10.1080/14640748808402298
- Caravolas, M., Hulme, C., & Snowling, M. J. (2001). The Foundations of Spelling Ability: Evidence from a 3-Year Longitudinal Study. *Journal of Memory and Language*, 45, 751-774. doi: 10.1006/jmla.2000.2785
- Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition*, 91(1), 77-111. doi: 10.1016/S0010-0277(03)00164-1

- Charlier, B. L., & Leybaert, J. (2000). The rhyming skills of deaf children educated with phonetically augmented speechreading. *The Quarterly Journal of Experimental Psychology*, 53A(2), 349-375. doi: 10.1080/713755898
- Colin, S., Magnan, A., Ecalle, J., & Leybaert, J. (2007). Relation between deaf children's phonological skills in kindergarten and word recognition performance in first grade. *Journal of Child Psychology and Psychiatry*, 48, 139-146. doi: 10.1111/j.1469-7610.2006.01700.x
- Connor, C. M., & Zwolan, T. A. (2004). Examining multiple sources of influence on the reading comprehension skills of children who use cochlear implants. *Journal of Speech, Language, and Hearing Research*, 47, 509-526. doi: 10.1044/1092-4388(2004/040)
- Conrad, R. (1979). *The Deaf School Child: Language and Cognitive Function*. London: Harper & Row.
- Daneman, M., Nemeth, S., Stainton, M., & Huelsmann, K. (1995). Working Memory as a Predictor of Reading Achievement in Orally Educated Hearing-Impaired Children. *The Volta Review*, 97, 225-241.
- DiFrancesca, S. (1972). *Academic Achievement Test Results of a National Testing Program for Hearing Impaired Students: United States, Spring 1971 (Report No. 9, Series D)*. Washington, DC: Gallaudet College, Office of Demographic Studies.
- Dodd, B. (1980). The Spelling Abilities of Profoundly Pre-lingually Deaf Children. In U. Frith (Ed.), *Cognitive Processes in Spelling* (pp. 423-440). London: Academic Press.
- Dyer, A., MacSweeney, M., Szczerbinski, M., & Green, L. (2003). Predictors of reading delay in deaf adolescents: the relative contributions of rapid

- automatized naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education*, 8(3), 215-229. doi: 10.1093/deafed/eng012
- Easterbrooks, S. R., Lederberg, A. R., Miller, E. M., Bergeron, J. P., & Connor, C. M. (2008). Emergent Literacy Skills During Early Childhood in Children With Hearing Loss: Strengths and Weaknesses. *The Volta Review*, 108(2), 91-114
- Elliot, C. D., Smith, P., & McCulloch, K. (1996). *British Ability Scales II (BAS II)*. Windsor, Berks: NFER-Nelson.
- Ellis, N., & Large, B. (1988). The early stages of reading: a longitudinal study. *Applied Cognitive Psychology*, 2(1), 47-76. doi: 10.1002/acp.2350020106
- France, N. (1981). *The Primary Reading Test*. Windsor, Berks: NFER-Nelson.
- Gates, A. I., & Chase, E. H. (1926). Methods and theories of learning to spell tested by studies of deaf children. *Journal of Educational Psychology*, 17(5), 289-300. doi: 10.1037/h0068697
- Geers, A., & Moog, J. (1989). Factors Predictive of the Development of Literacy in Profoundly Hearing-Impaired Adolescents. *The Volta Review*, 91, 69-86.
- Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research & Practice*, 16(4), 222-229. doi: 10.1111/0938-8982.00022
- Gombert, J.-E. (1992). *Metalinguistic Development*. London: Harvester Wheatsheaf.
- Goswami, U., & Bryant, P. (1990). *Phonological Skills and Learning to Read*. Hove, East Sussex: Lawrence Erlbaum Associates.
- Haptonstall-Nykaza, T. S., & Schick, B. (2007). The Transition From Fingerspelling to English Print: Facilitating English Decoding. *Journal of Deaf Studies and Deaf Education*, 12(2), 172-183. doi: 10.1093/deafed/enm003

- Harris, M., & Beech, J. R. (1998). Implicit Phonological Awareness and Early Reading Development in Prelingually Deaf Children. *Journal of Deaf Studies and Deaf Education*, 3(3), 205-216.
- Harris, M., & Moreno, C. (2004). Deaf children's use of phonological coding: evidence from reading, spelling and working memory. *Journal of Deaf Studies and Deaf Education*, 9(3), 253-268. doi: 10.1093/deafed/enh016
- Harris, M., & Moreno, C. (2006). Speech reading and learning to read: a comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education*, 11(2), 189-201. doi: 10.1093/deafed/enj021
- Hoffmeister, R. J. (2000). A Piece of the Puzzle: ASL and Reading Comprehension in Deaf Children. In C. Chamberlain, J. P. Morford & R. I. Mayberry (Eds.), *Language Acquisition by Eye* (pp. 143-163). Mahwah, NJ: Erlbaum Associates.
- Juel, C., Griffith, P., & Gough, P. (1986). Acquisition of literacy: a longitudinal study of children in first and second grade. *Journal of Educational Psychology*, 78(4), 243-255. doi: 10.1037/0022-0663.78.4.243
- Kenny, D. A. (1975). Cross-Lagged Panel Correlation: A Test for Spuriousness. *Psychological Bulletin*, 82(6), 887-903. doi: 10.1037/0033-2909.82.6.887
- Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education*, 11(3), 273-288. doi: 10.1093/deafed/enj037
- Kyle, F. E., & Harris, M. (2010). Predictors of reading development in deaf children: A 3-year longitudinal study. *Journal of Experimental Child Psychology*, 107, 229-243. doi: 10.1016/j.jecp.2010.04.011

- Leybaert, J., & Alegria, J. (1995). Spelling development in deaf and hearing children: Evidence for use of morpho-phonological regularities in French. *Reading and Writing: An Interdisciplinary Journal*, 7, 89-109. doi: 10.1007/BF01026949
- Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of Emergent Literacy and Early Reading Skills in Preschool Children: Evidence From a Latent-Variable Longitudinal Study. *Developmental Psychology*, 36(5), 596-613. doi: 10.1037/0012-1649.36.5.596
- Massaro, D. W. (1987). *Speech Perception by Ear and Eye: A paradigm for Psychological Inquiry*. Hillsdale, N.J.: Lawrence Erlbaum Associates.
- Masterson, J., Stuart, M., Dixon, M., & Lovejoy, S. (2003). *Children's Printed Word Database*: University of Essex.
- Mayer, C. (2007). What Really Matters in the Early Literacy Development of Deaf Children. *Journal of Deaf Studies and Deaf Education*, 12(4), 411-431. doi: 10.1093/deafed/enm020
- Miller, P. (1997). The Effect of Communication Mode on the Development of Phonemic Awareness in Prelingually Deaf Students. *Journal of Speech, Language, and Hearing Research*, 40(5), 1151-1163.
- Moore, D. F., & Sweet, C. (1990). Factors Predictive of School Achievement. In D. F. Moore & K. P. Meadow-Orlans (Eds.), *Educational and developmental aspects of deafness* (pp. 154-201). Washington, DC.: Gallaudet University Press.
- Morrison, C. M., Chappell, T. D., & Ellis, A. W. (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *The Quarterly Journal of Experimental Psychology*, 50A(3), 528-559. doi: 10.1080/027249897392017

- Musselman, C. (2000). How Do Children Who Can't Hear Learn to Read an Alphabetic Script? A Review of the Literature on Reading and Deafness. *Journal of Deaf Studies and Deaf Education*, 5(1), 9-31. doi: 10.1093/deafed/5.1.9
- Muter, V., Hulme, C., Snowling, M., & Taylor, S. (1998). Segmentation, Not Rhyming, Predicts Early Progress in Learning to Read. *Journal of Experimental Child Psychology*, 71(1), 3-27. doi: 10.1006/jecp.1998.2453
- Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: evidence from a longitudinal study. *Developmental Psychology*, 40(5), 665-681. doi: 10.1037/0012-1649.40.5.665
- Padden, C. A. (1991). The Acquisition of Fingerspelling by Deaf Children. In P. Siple & S. D. Fischer (Eds.), *Theoretical Issues in Sign Language Research Volume 2: Psychology* (pp. 191-210). Chicago, IL, USA: The University of Chicago Press.
- Padden, C. A., & Ramsey, C. (2000). American Sign Language and Reading Ability in Deaf Children. In C. Chamberlain, J. P. Morford & R. I. Mayberry (Eds.), *Language Acquisition by Eye* (pp. 165-189). Mahwah, New Jersey: Lawrence Erlbaum Associates.
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6(2), 174-215. doi: 10.1037/0278-7393.6.2.174

- Spencer, L. J., & Oleson, J. J. (2008). Early Listening and Speaking Skills Predict Later Reading Proficiency in Pediatric Cochlear Implant Users. *Ear and Hearing*, 29(2), 270-280. doi: 10.1097/01.aud.0000305158.84403.f7
- Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental Psychology*, 38(6), 934-947. doi: 10.1037/0012-1649.38.6.934
- Strong, M., & Prinz, P. M. (2000). Is American Sign Language skill related to English literacy. In C. Chamberlain, J. P. Morford & R. I. Mayberry (Eds.), *Language acquisition by eye* (pp. 131-141). Mahwah, NJ: Erlbaum Associates.
- Summerfield, A. Q. (1987). Some preliminaries to a comprehensive account of audio-visual speech perception. In B. Dodd & R. Campbell (Eds.), *Hearing by Eye: The Psychology of Lip-reading* (pp. 3-51). London: Lawrence Erlbaum Associates.
- Swanson, H. L., & Howell, M. (2001). Working memory, short-term memory, and speech rate as predictors of children's reading performance at different ages. *Journal of Educational Psychology*, 93(4), 720-734. doi: 10.1037/0022-0663.93.4.720
- Trezek, B. J., Wang, Y., Woods, D. G., Gampp, T. L., & Paul, P. V. (2007). Using Visual Phonics to Supplement Beginning Reading Instruction for Students Who Are Deaf or Hard of Hearing. *Journal of Deaf Studies and Deaf Education*, 12(3), 373-384. doi: 10.1093/deafed/enm014
- Trybus, R. J., & Karchmer, M. A. (1977). School Achievement Scores of Hearing Impaired Children: National Data on Achievement Status and Growth Patterns. *American Annals of the Deaf*, 122(2), 62-69.



- Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., et al. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: a 5-year longitudinal study. *Developmental Psychology*, 33(3), 468-479. doi: 10.1037/0012-1649.33.3.468
- Wauters, L. N., van Bon, W. H. J., & Tellings, A. E. J. M. (2006). Reading Comprehension of Dutch Deaf Children *Reading and Writing*, 19(1), 49-76.
- Ziegler, J. C., Stone, G. O., & Jacobs, A. M. (1997). What is the pronunciation for -ough and the spelling for /u/? A database for computing feedforward and feedback consistency in English. *Behavior Research Methods, Instruments, & Computers*, 29(4), 600-618.

Table 1: Means and standard deviations for Measures taken at Time 1, Time 2, and Time 3

	Time 1				Time 2				Time 3			
	Deaf		Hearing		Deaf		Hearing		Deaf		Hearing	
	Mean	Min/Max	Mean	Min/Max	Mean	Min/Max	Mean	Min/Max	Mean	Min/Max	Mean	Min/Max
	(SD)		(SD)		(SD)		(SD)		(SD)		(SD)	
Chronological age	5:08	4:11 –	5:00	4:08 –	6:08	5:11 –	5:11	5:08 –	7:11	7:02 –	7:02	6:11 –
	(4.7)	6:02	(1.8)	5:02	(4.9)	7:02	(1.7)	6:02	(5.0)	8:05	(1.8)	7:05
Word reading age	5:03	4:11 –	5:00	4:11 –	6:01	4:11 –	5:08	4:11 –	7:02	4:11 –	8:01	6:01 –
	(8.1)	6:10	(2.3)	5:10	(13.2)	8:03	(11.6)	8:03	(13.5)	10:09	(14.3)	10:09
Word reading raw	5.3	0 – 42	0.7	0 – 12	16.5	0 – 61	11.2	0 – 51	32.3	1 – 68	44.1	14 – 69
	(9.1)		(2.5)		(15.2)		(12.9)		(15.1)		(16.3)	
Spelling	2.4	0 – 14	0.6	0 – 4	7.7	0 – 23	6.0	1 – 16	14.3	0 – 26	15.7	8 – 25
	(3.6)		(1.1)		(6.2)		(4.0)		(6.0)		(5.2)	
Phonological	14.9	11 – 22	17.7	8 – 23	17.1	8 – 24	22.5	17 – 24	19.4	12 – 24	23.2	21 – 24
awareness (max 24)	(3.2)		(3.8)		(3.7)		(1.8)		(3.2)		(1.0)	
Speechreading	20.0	1 – 38	15.7	2 – 35	25.3	2 – 42	21.5	7 – 39	31.8	9 – 44	28.3	8 – 46

(max 50)	(10.7)		(8.9)		(10.5)		(9.5)		(10.0)		(8.8)	
Vocabulary	14.8	2 – 24	24.0	18 – 29	17.8	7 – 26	26.0	20 – 31	20.6	10 – 28	28.2	24 – 34
(max 38)	(5.6)		(3.5)		(4.0)		(3.0)		(3.8)		(2.7)	
Short-term memory	2.5	1.5 – 3.3	2.6	2 – 3.8	2.8	2 – 4	3.2	2.5 – 4	3.1	2 – 4.3	3.7	2.5 – 4.8
(max 6)	(0.4)		(0.4)		(0.4)		(0.4)		(0.6)		(0.5)	
Letter Names	18.0	0 – 26	9.3	0 – 24	23.4	6 – 26	20.7	7 – 26	24.9	20 – 26	25.6	22 – 26
(max 26)	(8.2)		(8.2)		(4.2)		(6.6)		(1.8)		(1.0)	
Letter Sounds	2.5	0 – 20	9.1	0 – 25	8.6	0 – 24	21.1	7 – 26	10.0	0 – 25	24.1	20 – 26
(max 26)	(4.7)		(8.2)		(8.3)		(3.9)		(9.2)		(1.8)	

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Table 2: Partial correlations between tasks taken at T1 controlling for NVIQ for Deaf children

	Hearing loss	Phonological awareness	Speechreading	Vocabulary	Short-term memory	Letter Names	Letter Sounds	Word reading	Spelling
Age	-.32	.15	.01	.20	.53**	.04	.28	.15	.26
Hearing Loss	--	-.27	-.04	-.10	-.09	.19	-.17	.02	-.24
Phonological awareness		--	.61**	.55**	.19	.01	.29	.58**	.62**
Speechreading			--	.86**	.33	.31	.25	.50**	.40
Vocabulary				--	.35	.25	.42*	.58**	.47*
Short-term memory					--	.42*	.04	.19	.22
Letter Names						--	-.19	.32	.34
Letter Sounds						α	--	.26	.27
Word reading									.88**

\*p<0.05; \*\*p<0.01

Table 3: Partial correlations between tasks taken at T1 controlling for NVIQ for Hearing children

	Phonological awareness	Speechreading	Vocabulary	Short-term memory	Letter Names	Letter Sounds	Word reading	Spelling
Age	.14	.32	.31	.20	-.04	.23	-.19	.03
Phonological awareness	--	.59**	.44*	.05	.18	.42*	.32	.39
Speechreading		--	.33	.01	.32	.32	.06	.26
Vocabulary			--	.18	.04	.68**	.32	.25
Short-term memory				--	.22	.18	.21	-.02
Letter Names					--	.17	.35	.63**
Letter Sounds						--	.60**	.56**
Word reading							--	.72**

\*p<0.05; \*\*p<0.01

Table 4: Partial cross-lagged correlations between tasks at T1 and T2/T3 controlling for NVIQ and earlier ability for Deaf children

	Phonological awareness		Speechreading		Vocabulary		Short-term memory		Letter Names		Letter Sounds		Word reading		Spelling	
	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3
Phonological awareness T1													.15	.38	-.33	-.01
Speechreading T1													.27	.64**	-.15	.18
Vocabulary T1													.52*	.72**	.04	.27
Short-term memory T1													.40	.10	.28	.14
Letter Names T1													.25	.19	.54**	.43*
Letter Sounds T1													.36	.48*	-.24	.01
Word reading T1	.50*	.20	-.15	-.35	.36	.33	.24	.10	.12	.11	.23	.33				
Spelling T1	.33	-.06	-.16	-.47*	.22	.40	.37	.14	.15	.12	.14	.20				

\*p < 0.05; \*\*p < 0.01

Table 5: Partial cross-lagged correlations between tasks at T1 and T2/T3 controlling for NVIQ and earlier ability for Hearing children

	Phonological awareness		Speechreading		Vocabulary		Short-term memory		Letter Names		Letter Sounds		Word Reading		Spelling	
	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3	T2	T3
Phonological awareness T1													.38	.66**	.52*	.53*
Speechreading T1													.56**	.58**	.73**	.54*
Vocabulary T1													.17	.35	.52*	.39
Short-term memory T1													-.18	-.06	.21	.06
Letter Names T1													.55**	.36	.24	.24
Letter Sounds T1													.41	.28	.39	.33
Word reading T1	.19	.06	.13	.31	-.07	.22	.27	-.44	-.07	-.08	.15	.01				
Spelling T1	.18	-.06	-.04	.25	-.04	.32	.22	-.30	.03	-.01	.26	.13				

\*p < 0.05; \*\*p < 0.01