Seven- and eight-year-old deaf children and hearing children of equivalent reading age were presented with a number of tasks designed to assess reading, spelling, productive vocabulary, speechreading, phonological awareness, short-term memory, and nonverbal intelligence. The two groups were compared for similarities and differences in the levels of performance and in the predictors of literacy. Multiple regressions showed that both productive vocabulary and speechreading were significant predictors of reading for the deaf children after hearing loss and nonverbal intelligence had been accounted for. However, spelling ability was not associated with any of the other measures apart from reading. For hearing children, age was the main determinant of reading and spelling ability (due to selection criterion). Possible explanations for the role of speechreading and productive vocabulary in deaf children’s reading and the differences between the correlates of literacy for deaf and hearing children are discussed.

It is well documented that deaf children often experience difficulties when learning to read, generally achieving lower levels of reading attainment in comparison to their hearing peers (e.g., Allen, 1986; Conrad, 1979; DiFrancesca, 1972; Lane & Baker, 1974; Lewis, 1996; Moog & Geers, 1985; Trybus & Karchmer, 1977) and leaving school with a typical reading delay of at least 5 years. Studies of spelling have also reported delays in achievement, although these delays are generally less severe than those exhibited for reading (e.g., Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Burden & Campbell, 1994; Gates & Chase, 1926; Hanson, Shankweiler, & Fischer, 1983; Hoemann, Andrews, Florian, Hoemann, & Jensema, 1976; Templin, 1948). Despite several decades of research, recent reviews (e.g., Marschark & Harris, 1996; Musselman, 2000) have not noted significant improvements in deaf children’s relative levels of achievement in reading and spelling.

One way of gaining a clearer understanding of how deaf children and adolescents learn to read and spell is to examine which cognitive and language-based skills predict individual differences in literacy achievement. For typically developing hearing children, it is widely accepted that phonological awareness—the ability to distinguish between and manipulate the constituent sounds of words—plays an important role in reading and spelling development and is one of the strongest predictors of literacy achievement, especially in the early stages (for reviews, see Adams, 1990; Castles & Coltheart, 2004; Goswami & Bryant, 1990; Wagner & Torgesen, 1987). As the ability to read and write can be thought of as being parasitic upon language, the corollary of this assumption is that oral language skills, both expressive and receptive, are important for reading and spelling. Indeed, strong predictive relationships have also been observed between language skills, including vocabulary, and reading ability (e.g., Bowey & Patel, 1988; Dickinson, McCabe, Anastasopoulos, Peisman-Feinberg, & Poe, 2003; Juel,
Griffith, & Gough, 1986; Snow, Tabors, & Dickinson, 2001; Tunmer & Nesdale, 1985). The importance of other cognitive and language-based skills, such as short-term memory (e.g., Ellis & Large, 1987; Leather & Henry, 1994; Swanson & Howell, 2001), grammatical knowledge (Muter, Hulme, Snowling, & Stevenson, 2004), orthographic knowledge (Lennox & Siegel, 1994), and morphological skills (Deacon & Kirby, 2004), has also been highlighted.

In contrast to the converging findings from hearing children, fairly equivocal findings have emerged from similar studies of reading in deaf children. Although there have been many studies looking at which skills are associated with reading ability, few have considered more than one ability in the same study, and so they do not show the relative contributions of each skill. As with hearing children, the main concern has been with the role of phonological awareness and with two related questions: firstly, whether deaf children and adolescents can be considered to be phonologically aware and, secondly, whether performance on tasks that measure phonological awareness is associated with reading and spelling ability.

Many researchers have concluded that, although deaf teenagers and college students “can” make judgments based upon the rhyme properties of both pictures and words, they are generally less accurate and slower than hearing individuals matched on either chronological age or reading ability (e.g., Campbell & Wright, 1988; Dodd & Hermelin, 1977; Dyer, MacSweeney, Szczersinski, & Green, 2003; Hanson & Fowler, 1987; LaSasso, Crain, & Leybaert, 2003; Leybaert & Alegria, 1993). There is less consensus from research with deaf school children. Three studies report comparatively high levels of awareness (Charlier & Leybaert, 2000; Miller, 1997; Sterne & Goswami, 2000), whereas the remaining two report much lower levels (Harris & Beech, 1998; Izzo, 2002). Harris and Beech (1998) found that 5-year-old deaf children were significantly worse than their hearing peers on a picture-based task of rhyme judgment (61% to 81%) and that many were performing below or around chance levels. Miller (1997) found that older deaf children, aged between 9 and 14 years, performed above chance level on a picture rhyme-matching task, involving both orthographically congruent and incongruent items. However, the deaf children’s performance was commensurate with that of their hearing peers only when items were orthographically congruent. Many other authors have also suggested that deaf adolescents and children are heavily influenced by or rely upon orthography when making judgments of phonological similarity (Campbell & Wright, 1988; Hanson & Fowler, 1987; Hanson & McGarr, 1989; Sterne & Goswami, 2000).

Turning to the existence of a relationship between phonological awareness and reading and spelling ability in deaf children and adolescents, only three studies report strong relationships. Harris and Beech (1998) found a positive association (.43) between phonological awareness and progress in reading ability over 1 year in beginning deaf readers. Likewise, Campbell and Wright (1988) observed a correlation of .54 between accuracy on the incongruent items of a rhyme judgment task and reading age and Dyer et al. (2003) found that reading age was related to accuracy on a rhyme judgment task (.39) and pseudohomophone matching task (.46). However, many other authors have not found a significant relationship (Hanson & Fowler, 1987; Hanson & McGarr, 1989; Izzo, 2002; Leybaert & Alegria, 1993; Miller, 1997).

Some of these differences in results can be explained by the tasks used and the abilities of the participants. For example, although Izzo (2002) found no association between phonological awareness and reading, the measure of reading was a story-retelling task, which makes use of a number of high-level skills including the ability to summarize and memorize. Additionally, there were severe floor effects in the phonological awareness task in Izzo’s study, which may have precluded a significant association. Neither of the Hanson studies (Hanson & Fowler, 1987; Hanson & McGarr, 1989) found a relationship between reading and phonological awareness in college-age deaf students, who were already comparatively good readers and well educated, and this may suggest that phonological ability is only related to reading ability in the earlier stages of development. An alternative explanation, suggested by Musselman (2000), is that phonological ability predominately develops as a consequence of learning to read in deaf individuals rather than being more of a prerequisite, as in hearing
children. This interpretation is consistent with the conclusion that the strongest evidence of phonological awareness comes from studies involving older deaf adolescents and college students.

As there is no clear evidence of the role of phonological awareness in deaf children’s literacy, other possible correlates of reading ability have been investigated. Language delay has been described as being a hallmark of deafness (Musselman, 2000), and many studies have reported that deaf adolescents have poorer vocabulary knowledge than would be expected for their age or in comparison with hearing adolescents (e.g., Geers & Moog, 1989; Moores & Sweet, 1990; Waters & Doehring, 1990). Taking this into consideration, along with the importance of language for typically reading hearing children, it is unsurprising that language and vocabulary knowledge have been found to be strong correlates of reading ability in deaf children and adolescents (Harris & Beech, 1998; Izzo, 2002; LaSasso & Davey, 1987; Moores & Sweet, 1990; Waters & Doehring, 1990).

Several studies have reported strong correlations between speechreading (silent lipreading) and reading in deaf adolescents (Arnold & Kopsel, 1996; Campbell & Wright, 1988; Cue, 1996; Geers & Moog, 1989). For example, Arnold and Kopsel (1996) found that speechreading ability was the only significant correlate of reading ability in 10 orally educated severely and profoundly deaf children, although they did not find a significant relationship for 10 bilingually educated deaf children. The strongest evidence to date, of the importance of speechreading skills for reading ability, comes from a recent study of good and poor deaf readers by Harris and Moreno (2006). The authors found that speechreading ability was the only skill that correctly identified all the good deaf readers (8-year olds). However, although it clustered all the good readers together, it also included the majority of the poor readers. Thus, although all the good readers had good speechreading skills, it appeared that many of the poor readers also had good speechreading skills, despite being poor readers, suggesting that good speechreading skills alone are not sufficient for success in learning to read.

Short-term memory has also been found to be both a strong correlate and predictor of reading ability in older deaf children and adolescents (Daneman, Nemeth, Stainton, & Huelsmann, 1995; Harris & Moreno, 2004; MacSweeney, 1998; Waters & Doehring, 1990); however, this relationship appears to be dependent upon the age of the deaf participants as no significant association was found in deaf 7- and 8-year olds.

The present study compared two groups of deaf and hearing children, matched on reading age, on a range of reading, spelling, cognitive, and language-based tasks to examine similarities and differences in levels of performance and in the correlates and predictors of literacy. As the majority of previous studies have been correlational in design, this study will also investigate the predictors of literacy achievement in deaf children. The research questions of interest were as follows: How would deaf and hearing children compare in their performance on cognitive and language-based skills hypothesized to be important for literacy? What are the correlates of reading and spelling achievement in deaf school-age children, and which skills account for the individual differences observed in literacy ability? Do deaf children show the same pattern of correlates and predictors of reading and spelling ability as hearing children?

The current study also provided an opportunity to examine whether several experimental effects, previously reported in separate studies of deaf adolescents, could also be observed in the same group of deaf school children from mixed language backgrounds. It has been reported that deaf adolescents are sensitive to spelling-to-sound regularities when spelling as they are more accurate on items for which the spelling is consistent (Burden & Campbell, 1994; Leybaert & Alegria, 1995; Sutcliffe, Dowker, & Campbell, 1999). Likewise, it has also been observed that deaf children and adolescents are more accurate in making phonological judgments when the orthography and phonology of the word are congruent such as train-rain than when the items are orthographically incongruent such as eye-fly (Campbell & Wright, 1988; Hanson & Fowler, 1987; Hanson & McGarr, 1989; Miller, 1997; Sterne & Goswami, 2000). These experimental manipulations were also examined in the current study.
Method

Participants

Twenty-nine 7- and 8-year-old deaf children (12 boys and 17 girls) and 31 reading-age matched hearing children (13 boys and 18 girls) participated in the study. The deaf children were recruited and tested initially, and then the hearing children were selected to match the deaf group on reading age (for single words in isolation) using the Single Word Reading subtest from the British Ability Scales II (BAS II; Elliot, Smith, & McCulloch, 1996). Written parental permission was given for all participating children.

Deaf children. The deaf children ranged in age from 6 years 8 months to 8 years 7 months with a mean age of 7 years 10 months (SD = 7.0 months). The mean reading age for the deaf children, using the BAS II Single Word Reading subtest (Elliot et al., 1996), was 6 years 10 months (SD = 9.5 months). The criteria for inclusion were that all deaf children (1) were prelingually deaf (before the age of 2 years); (2) had a severe or profound hearing loss of greater than 71 db; (3) had a nonverbal intelligence (NVIQ) composite score of at least 85 (estimated using three subtests from the BAS II; Elliot et al., 1996); and (4) had no additional cognitive, social, or significant behavioral problems. The mean hearing loss for the group was 99 db (SD = 11.0) and ranged from 71 db to greater than 120 db. All the children wore hearing aids, and seven were fitted with cochlear implants. Nine of the children (31%) had at least one deaf parent (Deaf of Deaf), and the other 20 had hearing parents (Deaf of Hearing).

The sample is representative of the diversity of educational settings in which deaf children are taught in England (Gregory & Hindley, 1996). Nine different specialist schools for the Deaf or hearing-impaired units attached to mainstream schools around the South East of England participated. The children varied considerably with respect to the communication method through which they were taught (bilingual, total communication, or oral), the communication method used at home, their language preference, and their signing skills. Signing was the preferred communication method for 18 of the children, 4 preferred to use total communication—a combination of sign and spoken language—and the remaining 7 used spoken language.

Hearing children. The mean age of the hearing children was 6 years 9 months (SD = 10.3 months) and ranged from 5 years 4 months to 8 years 7 months. They were all determined to be reading age appropriately (within 6 months of their chronological age), using the BAS II Single Word Reading subtest (Elliot et al., 1996), and were matched to the deaf children on their resulting reading ages from this test. They were predominately matched on a one-to-one basis, apart from five children who could not be matched exactly but were up to 2 months the other side. The large age range of the hearing children was a result of the predominately one-to-one matching criterion. All children achieved a score of at least 85 on a measure of nonverbal intelligence (BAS II Matrices subtest; Elliot et al., 1996).

The hearing children were all pupils in the mainstream schools to which the hearing units were attached to ensure that the deaf and hearing children were matched for demographic variables. There were no significant differences between the deaf and hearing children on reading age, \( t(58) = 0.25, \text{ ns} \), or nonverbal intelligence, \( t(44) = 0.56, \text{ ns} \).

Tasks

The children were given two reading tests to measure different components of the reading process: single-word reading ability and sentence comprehension. Measures were also taken of their spelling ability, nonverbal intelligence (NVIQ), phonological awareness, productive vocabulary, short-term memory span, and speechreading ability.

Reading ability. All children were given two standardized tests of reading; one measuring single-word reading ability (Single Word Reading subtest, BAS II; Elliot et al., 1996) and the other measuring word-recognized and sentence comprehension skills (Primary Reading Test, France, 1981). Although the single-word reading test was used to initially match the deaf and hearing children, it was also used, alongside the sentence comprehension test, as a reading outcome.
measure. Children could respond using their preferred communication method: signing, speech, or a combination of the two. The instructions were given as per the manual but in the child’s preferred language. The maximum score for the single-word reading test was 90, and for the sentence comprehension test it was 48.

**Spelling ability.** The children were given a spelling-to-picture task, in which they were presented with 30 pictures, one at a time, and asked to write down the name of the picture. The 30 words depicted were concrete nouns, varying in syllabic length (monosyllabic, disyllabic, trisyllabic or quad-syllabic) and regularity (regular or irregular). The words were classified as being regular if there was only one, or a dominant, way of graphemically representing the combination of constituent letters, using phonology-to-spelling feedback consistency (see Ziegler, Stone, & Jacobs, 1997).

All words were characterized as being of high frequency (see norms from Kucera & Francis, 1967) and early acquired (see age of acquisition norms from Morrison, Chappell, & Ellis, 1997) and therefore would be expected to be in most typically developing children’s vocabularies. The words were depicted using black and white line drawings taken mainly from Snodgrass and Vanderwart (1980) and were considered to be highly familiar and have low visual complexity (see norms from Cycowicz, Friedman, Rothstein, & Snodgrass, 1997). The maximum score was 30.

**Productive vocabulary.** This was assessed using the productive vocabulary subtest from the BAS II (Elliot et al., 1996). To answer correctly, children had to produce (using speech, sign, or a combination of both) the correct name for each object, not simply a spoken or signed description. The instructions from the manual were given in the child’s preferred language. The maximum possible score was 32.

**Phonological awareness task.** This was adapted from Harris and Beech (1998) and measured the child’s ability to make a judgment of phonological similarity. Children were shown a brightly colored folder containing 24 pages with three pictures on each. The picture at the top of the page was the item and underneath were a target and a distracter. The first section (consisting of 12 sets of pictures) required the child to make a judgment of alliteration similarity (onset), and the second (12 sets), a judgment of rhyme similarity (rime).

In the rime section, the orthographic congruency of the items was controlled: half the trials contained items and targets that were phonologically and orthographically congruent (e.g., snake-cake), and the other half contained items that were phonologically and orthographically incongruent (e.g., eye-fly). On the congruent trials, the children could choose the correct target simply by relying on orthographic cues to judge whether it rhymed with the item and would not necessarily need to use any phonological information. The incongruent trials, however, could only be judged correctly by using phonological knowledge, as the spelling was incongruent.

The words depicted were all characterized as being high-frequency (see norms from Masterson, Stuart, Dixon, & Lovejoy, 2003) early age of acquisition words (see norms from Morrison et al., 1997). Words in the onset and rime sections were matched for word frequency, age of acquisition, and also on the density of their phonological and orthographic neighborhoods (using database from Masterson et al., 2003).

Children were initially pretested on all the pictures. In addition to the test proper, there were two practice trials at the beginning of each section during which children could be given feedback. Children were shown the first practice trial and asked to name the top picture (the item), while the other two pictures were hidden. They were shown the other two pictures and asked to name them and to indicate which of the two bottom pictures began with the same sound as the top picture, for example, bat, bag, man. The same procedure was followed for the rime section, apart from being asked which of the two bottom pictures ended with the same sound as the top picture, for example, fox, bath, box. Once the test proper had begun, no feedback was provided. The maximum score was 24.

**Short-term memory span.** This task measured visual, sequential short-term memory span and was developed from the short-term memory span task used in Harris and Moreno (2004). The task was presented on
a laptop computer. The children were shown trials of increasing numbers of pictures to recall in the correct order. The minimum number of pictures presented was two and the maximum was six, with three trials at each list length. The test was progressive and stopped when the child made errors on two or more trials at a given list length. The span was calculated as the maximum number of items that the child could correctly recall on two out of the three trials, and they were given a half point if they recalled one out of the three trials correctly. The task had two sections: the first provided a span of pictures representing words of one syllable in length (e.g., bike, fox, tent, lips) and the second a span of pictures representing two-syllable words (e.g., apple, flower, rabbit, button). Short-term memory span was taken as the average over the two word lengths.

The words used in the task were characterized as being of high frequency (see Masterson et al., 2003) and acquired early (see Morrison et al., 1997). The words were matched on these properties between the two sections. They were depicted by black and white line drawings taken from the Snodgrass and Vanderwart (1980) database. In each trial, the pictures were dissimilar in terms of their phonological, visual, and sign properties. Children were initially pretested on the pictures. They were allowed to give their answers in their preferred language: sign language, spoken English, or a combination of the two. There were three practice trials during which feedback was provided. Once the task proper had begun, no feedback was provided. Presentation of the two sections was counterbalanced. The maximum score was 6.

Speechreading. The measure of speechreading ability for single words was taken from Harris and Moreno (2006). Children were shown a video of a woman saying the name of an object (without sound), and they had to point to the corresponding object in a picture array on a board in front of them. There were five different picture boards and 10 trials on each. Children were told that the same pictures could occur twice.

On the first board, the items differed in syllable length and onset and rime (e.g., ball, apple, butterfly). The second board consisted of two-syllable words that differed in onset and rime (e.g., pencil, dolphin, flower). On the third board, all the items were monosyllabic and began with the same onset and thus measured the child’s ability to differentiate between the endings of words (e.g., ball, box, bus). The items on boards four and five were also monosyllabic but ended with the same rime thus requiring the child to distinguish between the beginnings of words (board 4: pear, hair, fair; board 5: bee, tree, key). The rationale for the discriminations required for the different boards came from Geers (1994).

Children were given the following instructions: “we are going to watch a video. The video is of a lady. The lady will say the name of something on this board (the experimenter pointed to the board) and you have to point to what you think she says. Maybe, the lady will say shoe and then you would point to shoe. But you will not be able to hear what the lady says, you must try and lipread.” The instructions were specifically designed so that they could be signed or spoken to mean exactly the same. The order of presentation of the different boards was counterbalanced. The maximum possible score was 50.

Procedure

The children were seen individually on six separate occasions, with each session lasting no more than 20 minutes. Testing took place in a quiet room, usually adjacent to the classroom. For the deaf children, all instructions were delivered using the child’s preferred communication method, either signing or spoken English. For the hearing children and orally educated deaf children, all instructions were given using spoken English. All BAS II subtests and the Primary Reading Test were administered as per the instruction manuals.

Results

The experimental tasks were found to be statistically reliable as Cronbach’s alpha, for all was above the accepted criterion of 0.7. All data distributions were examined, and where evidence was found of significant skewness or kurtosis, the data were transformed following guidelines from Tabachnick and Fidell (2001).
Reading and Spelling Achievements

Reading. The means and standard deviations can be seen in Table 1. The reading achievements of the deaf children were generally not age appropriate, $t(28) = 6.4$, $p < .001$, 95% CI: 8.35–16.20, and there was a mean delay in single-word reading age of 13 months (mean reading age was 6 years 10 months, and mean chronological age was 7 years 10 months). The deaf children’s single-word reading delay ranged from 6 months above chronological age to 37 months below. In comparison, due to the selection criteria, the hearing children were reading age appropriately. There were no significant differences between the deaf and hearing children on the measure of sentence comprehension, $t(58) = 0.94$, ns, 95% CI: -.23 to .08. Both groups appeared to perform relatively poorly on the sentence comprehension test, as only 9 children (4 deaf and 5 hearing) scored highly enough to be given a reading age of 6 years or more on this test, in comparison with the single-word reading test on which 53 children achieved a reading age of 6 years or above.

Spelling. There were no statistically significant differences between the deaf and hearing children in their overall spelling scores, $t(58) = 1.77$, ns, 95% CI: −.31 to 5.1, and both groups could spell on average fewer than half the words correctly. The monosyllabic words varied in terms of their sound-to-spelling regularity. A two-way mixed-design analysis of variance (ANOVA; regularity by group) revealed a large regularity effect in that more regular than irregular monosyllabic words were spelt correctly, $F(1,58) = 249.51$, $p < .001$, $\eta^2 = .43$, but no main effect of group, $F(1,58) = 2.14$, ns, $\eta^2 = .017$ or significant interaction, $F(1,58) = 0.50$, ns.

Performance on Language and Cognitive Tasks

Phonological awareness. The deaf children’s accuracy, as a group, was above chance as the mean score was 17.8/24 (74%), and binomial distribution tables revealed that scores over 16.8 were unlikely to have been achieved by chance alone ($p < .05$). A two-way ANOVA (group by section) revealed a main effect of group, whereby the hearing children were more accurate than the deaf children, $F(1,58) = 19.26$, $p < .001$, $\eta^2 = .17$. There was also a main effect of section, whereby the children achieved higher scores on the items requiring a judgment of onset similarity compared to the items requiring a judgment of rime similarity, $F(1,58) = 6.20$, $p = .016$, $\eta^2 = .02$ but no significant interaction, $F(1,58) = 2.27$, ns, $\eta^2 = .01$.

A second two-way mixed-design ANOVA (group by congruency), investigating performance on the rime items for orthographic congruency effects, found a small to medium main effect of congruency, $F(1,58) = 18.30$, $p < .001$, $\eta^2 = .25$, a large main effect of group, $F(1,58) = 19.07$, $p < .001$, $\eta^2 = .26$ but no significant interaction, $F(1,58) = 0.10$, ns. Therefore, the hearing children achieved higher scores than the deaf children on the rime items, regardless of whether the items were orthographically congruent or not. Additionally, both deaf and hearing children did better when the rime items were orthographically and phonologically congruent.

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**Table 1** Mean scores for deaf and hearing children on assessments

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<thead>
<tr>
<th></th>
<th>Deaf children (n = 29)</th>
<th></th>
<th>Hearing children (n = 31)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Means (SD)</td>
<td>Min/Max</td>
<td>Means (SD)</td>
<td>Min/Max</td>
</tr>
<tr>
<td>Chronological age</td>
<td>7.10 (7.0)</td>
<td>6.08–8.07</td>
<td>6.09 (10.3)</td>
<td>5.04–8.07</td>
</tr>
<tr>
<td>Reading age</td>
<td>6.10 (9.5)</td>
<td>5.01–8.03</td>
<td>6.09 (10.0)</td>
<td>5.01–8.03</td>
</tr>
<tr>
<td>Single word reading</td>
<td>26.8 (11.6)</td>
<td>6–48</td>
<td>25.5 (12.7)</td>
<td>6–53</td>
</tr>
<tr>
<td>Sentence comprehension</td>
<td>15.1 (4.6)</td>
<td>5–24</td>
<td>16.1 (4.9)</td>
<td>10–30</td>
</tr>
<tr>
<td>Spelling</td>
<td>13.5 (5.3)</td>
<td>1–23</td>
<td>11.1 (5.2)</td>
<td>3–22</td>
</tr>
<tr>
<td>Phonological awareness</td>
<td>17.8 (4.0)</td>
<td>10–23</td>
<td>21.5 (2.3)</td>
<td>15–24</td>
</tr>
<tr>
<td>Productive vocabulary</td>
<td>19.8 (2.5)</td>
<td>15–25</td>
<td>27.1 (3.1)</td>
<td>20–33</td>
</tr>
<tr>
<td>Short-term memory span</td>
<td>2.9 (0.7)</td>
<td>1.25–4.50</td>
<td>3.3 (3.3)</td>
<td>1.75–4.25</td>
</tr>
<tr>
<td>Speechreading</td>
<td>27.4 (10.8)</td>
<td>6–43</td>
<td>19.9 (11.1)</td>
<td>1–34</td>
</tr>
</tbody>
</table>
Productive vocabulary. The deaf children, as a group, were delayed in their productive vocabulary as the mean age-equivalent vocabulary age was 3 years 7 months, which was significantly lower than their mean chronological age, $t(28) = -21.60$, $p < .001$, 95% CI: $-55.61$ to $-45.98$, whereas the hearing children’s vocabularies were age-appropriate, $t(30) = 0.75$, ns. The hearing children had significantly larger productive vocabularies than the deaf children, $t(58) = -10.04$, $p < .001$, $d = 2.59$.

Short-term memory. A two-way mixed-design ANOVA (hearing status by word length) revealed that there were no statistically significant differences between the deaf and hearing children in their short-term memory spans, $F(1,58) = 3.60$, ns, $\eta^2 = .045$. There was no main effect of word length, $F(1,58) = 3.92$, ns, $\eta^2 = .01$, although this only just failed to achieve significance ($p = .052$). There was also no interaction between group and word length, $F(1,58) = 2.16$, ns.

Speechreading. A two-way mixed-design ANOVA (group by board) revealed a medium main effect of group, $F(1,55) = 6.73$, $p = .012$, $\eta^2 = .07$, a medium main effect of board, $F(4,220) = 19.51$, $p < .001$, $\eta^2 = .09$, but no significant interaction, $F(4, 220) = 1.52$, ns. Thus, although the deaf children achieved significantly higher overall scores than the hearing children on the speechreading task, a similar pattern, across the boards, was exhibited by both groups. Post hoc analysis (Bonferroni $t$ tests) showed that although children scored better on boards 1, 2, and 4, their performance was similar across these three boards. Likewise, although children scored less well on boards 3 and 5, there were no differences between performances on these two boards.

Relationships Between Reading, Spelling, and the Language and Cognitive Tasks

The data were then analyzed using partial correlations and fixed-order multiple regression analyses. The results will be reported separately for the deaf and hearing children.

Deaf children. Table 2 shows the partial correlations, controlling for the effects of hearing loss, between reading and spelling and the other abilities. Hearing loss was removed from the correlations because the degree of hearing loss exhibited strong negative relations with reading, phonological awareness, vocabulary, and speechreading. As can be seen in Table 2, both reading tests were strongly correlated with each other and spelling, speechreading, and productive vocabulary. Neither reading test was significantly associated with age, nonverbal intelligence (NVIQ), phonological awareness, or short-term memory span once the effects of hearing loss were controlled. Before hearing loss was statistically controlled, the zero-ordered correlations had shown a significant correlation between both reading tests and phonological awareness.

Spelling ability did not exhibit the same pattern of associations as reading ability, as the only significant
correlation was with the two reading tests, and no significant relations were found with any of the other variables. Moreover, spelling ability was not affected by the degree of hearing loss. There were significant small to medium intercorrelations between speechreading, phonological awareness, and vocabulary. Speechreading was also found to have a medium association with NVIQ.

Fixed-ordered multiple regression analyses were conducted to investigate which of the literacy-related tasks explained variance in performance on the two reading and spelling tests. The current sample size of 29 participants is just below the recommended sample size of 31 that is sufficient to detect a large effect with three predictors (Green, 1991), and therefore, the findings need to be interpreted with a note of caution.

As can be seen in Table 3, when NVIQ and hearing loss were entered in Steps 1 and 2, they explained 27% of the variance in the single-word reading scores. Productive vocabulary was then entered in Step 3, and it accounted for almost 15% of additional variance in performance in the single-word reading ability. When speechreading was entered instead of vocabulary, in Step 3, it explained almost 26% of additional variance. Both speechreading and vocabulary represented a medium effect on the single-word reading scores. A similar pattern was found when the sentence comprehension test was the outcome variable. NVIQ and hearing loss were again entered into the regression analyses at Steps 1 and 2 and explained 41% of the variance in scores. When vocabulary was entered in Step 3, it accounted for an additional 28% of the variance. If speechreading was entered in Step 3 instead, it explained an additional 14% of the variance.

As performance on the spelling task did not show any significant associations with any of the other variables apart from the reading tasks, multiple regression analyses were not conducted with spelling as the outcome variable.

Hearing children. In light of the 3-year age range of the hearing children, age was statistically controlled in all analyses. As can be seen in Table 4, after the effects of age had been controlled, the only partial correlations that were statistically significant were between single-word reading ability and spelling ability and

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<th>Table 4</th>
<th>Concurrent correlates of reading and spelling ability in hearing children (controlling for age)</th>
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<tbody>
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<td></td>
<td>SWR</td>
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<td>Matrices</td>
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<td>SWR</td>
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<td>SCR</td>
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<td>Spelling</td>
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<td>PA rime</td>
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<td>Speechr</td>
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<td>Vocab</td>
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* Note. SWR: single-word reading raw scores; SCR: sentence comprehension; Spelling: spelling; PA rime: rime section from phonological awareness task; Speechr: speechreading; Vocab: productive vocabulary; STM: short-term memory span.

* p < .05; ** p < .01.
between spelling ability and the rime phonological awareness scores. Sentence comprehension was not significantly associated with any of the variables. As performance on the reading tasks did not show any significant associations with any of the other variables apart from age, multiple regression analyses were not conducted with either reading tasks as the outcome variable. Fixed-order multiple regression analyses were carried out to determine which abilities explained performance on the spelling task (Table 5). When spelling was the outcome variable and age was entered in Step 1, it accounted for 52% of the individual differences in the spelling scores. Rime phonological awareness scores were entered into the regression equation in Step 2 and explained a further 8% of additional variance over and above that accounted for by age in the spelling scores.

Differences Between Those Children with Cochlear Implants and Hearing Aids

The data were also examined to see if there were any differences in literacy attainment and performance on the cognitive and language tasks between children with cochlear implants or hearing aids. The children with cochlear implants achieved significantly lower scores on the tests measuring reading ability, spelling, and short-term memory than the hearing-aided children. However, it should be noted that implantation was relatively late in all cases, having occurred at between 3 and 6 years of age. At the time of assessment, the children had only been using their implants from between 1 year 8 months to 4 years 5 months. Taking these factors into account, along with the comparatively small sample size of children with cochlear implants (n = 7), these results must be interpreted with caution.

Table 5 Predictors of spelling ability in the hearing children

<table>
<thead>
<tr>
<th>Step</th>
<th>Independent variable</th>
<th>R2</th>
<th>R2 change</th>
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<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>.515</td>
<td>.515*</td>
</tr>
<tr>
<td>2</td>
<td>PA rime</td>
<td>.592</td>
<td>.076**</td>
</tr>
</tbody>
</table>

Note. PA rime: rime section from phonological awareness task. *p < .01; **p < .05.

Summary of Results

Although the deaf and hearing children’s performances were generally qualitatively similar on all tasks, as they exhibited the same experimental effects, there were important quantitative differences between the two groups. The hearing children were more accurate on the phonological awareness and productive vocabulary tasks, whereas the deaf children were more accurate on the speechreading task. The two groups did not differ in their spelling ability or short-term memory span. When the relationships between reading, spelling, and other skills were examined, differences were found between the predictors of literacy in deaf and hearing children although, due to the effects of age, the predictors of reading in hearing children were difficult to determine precisely. For the deaf children, reading and spelling were themselves highly associated yet exhibited different patterns of correlates and predictors. After controlling for degree of hearing loss, productive vocabulary and speechreading (language factors) were significant predictors of reading achievement, but spelling ability was not significantly associated with any of the other variables.

Discussion

The principle aim of the study was to compare two groups of deaf and hearing children, matched for reading ability, on a range of reading, spelling, and literacy-related tasks, in order to examine similarities and differences in their relative levels of performance and in the concurrent correlates and predictors of reading and spelling.

The levels of reading and spelling observed in this study are largely consistent with previous findings in that deaf children, as a group, were significantly delayed in their reading ability (e.g., Allen, 1986; Banks, Gray, & Fyfe, 1990; DiFrancesca, 1972; Harris & Moreno, 2004). It cannot be determined whether the deaf children’s performance on the spelling task was age appropriate as the test was not standardized; however, as there were no significant differences in the overall spelling abilities between the deaf and younger hearing children in this study (matched on reading level), this could suggest that the deaf
children’s spelling abilities were delayed for their chronological age although appropriate for their reading level (Harris & Moreno, 2004).

The presence of spelling regularity effects suggests that young deaf children, like hearing children (see Bruck & Waters, 1990; Treiman, 1984, 1993; Waters, Bruck, & Seidenberg, 1985) and older deaf adolescents (see Burden & Campbell, 1994; Leybaert & Alegria, 1995; Sutcliffe et al., 1999), have some knowledge of the relationship between sounds and their corresponding written form. This might reflect either an implicit sensitivity to phonological information or the use of an explicit phonological coding strategy (see Leybaert & Alegria, 1995; Sutcliffe et al.). However, as in previous studies, the deaf children showed less detailed phonological knowledge than hearing children of the same reading age as evidenced by their lower performance in the phonological awareness task.

Turning to performance on the literacy-related tasks, the general pattern was of lower performance by the deaf children. They were delayed in their productive vocabulary when compared to both hearing norms and hearing children of the same reading age (Cue, 1996; Dodd, McIntosh & Woodhouse, 1998; Dodd, Woodhouse, & McIntosh, 1992; Geers & Moog, 1989; Moores & Sweet, 1990; Waters & Doehring, 1990). As already noted, they were less accurate than the hearing children on the phonological awareness task (Campbell & Wright, 1988; Harris & Beech, 1998; Izzo, 2002; Miller, 1997; Sterne & Goswami, 2000, experiments 2 and 3), although they did perform above chance levels and so therefore could be considered to be phonologically aware. Both groups were affected by the orthographic congruency of the rime items, confirming previous suggestions that deaf children may be relying upon orthographic knowledge to complete these tasks (Campbell & Wright, 1988; Charlier & Leybaert, 2000; Sterne & Goswami, 2000).

Deaf and hearing children did not differ significantly on short-term memory span, indicating that the deaf children’s memory spans were equivalent to those of younger reading age-matched hearing children. This supports earlier findings (Campbell & Wright, 1990; Harris & Moreno, 2004; MacSweeney, 1998).

There was only one task on which the deaf children outperformed hearing children. This was speech-reading. Our finding contradicts previous studies that report equivalent speechreading skills in deaf and hearing adolescents (Conrad, 1977) and children (Arnold & Kopsel, 1996) but supports the findings of Lyxell and Holmberg (2000). There were some differences between the present study and earlier research. Both Conrad and Arnold and Kopsel contrasted deaf and hearing individuals matched for chronological age, whereas the children were matched for reading level in the current study. However, as the language skills of the hearing children were better than those of the deaf children, it is hard to see how this can account for the difference in the findings. Another factor was the speechreading task itself, which presented video clips of the speaker and used brightly colored pictures. This may have made the task easier for the children and so allowed the superior skills of the deaf children to emerge.

The most significant finding from this study was that the concurrent correlates and predictors of reading and spelling were different for deaf and hearing children. For the deaf children, reading achievement was predicted by the degree of hearing loss, speechreading, and productive vocabulary. However, spelling ability in the deaf children was not associated with any of the other variables apart from reading ability, not even hearing loss. This pattern was consistent with findings from previous correlational studies suggesting that speechreading (Arnold & Kopsel, 1996; Campbell & Wright, 1988; Cue, 1996; Geers & Moog, 1989; Harris & Moreno, 2006) and vocabulary knowledge (Geers & Moog, 1989; LaSasso & Davey, 1987; Moores & Sweet, 1990) could be important for reading ability in deaf children. What the present study established was that both factors appear to be important for reading. In addition, the results suggested a disparity in the relative contributions made by vocabulary and speechreading to the different components of reading: speechreading was the strongest predictor of single-word reading ability, whereas productive vocabulary was the strongest predictor of sentence comprehension ability. The study also points to the need for further research to uncover the spelling strategies that deaf children use because these appear to be different from their reading strategies.
For hearing children of similar age, there is generally a strong relationship between reading and spelling (Caravolas, Hulme, & Snowling, 2001; Jorm, 1981; Juel et al., 1986; Nation & Hulme, 1997; Snowling & Perin, 1982) and, more importantly, a similarity in the correlates of reading and spelling (Bryant, MacLean, & Bradley, 1990; Caravolas et al., 2001; Ellis & Large, 1988; Juel et al., 1986). The pattern emerging for the deaf children in this study is thus rather different from what has been observed for hearing children in previous studies. It should be noted in this context that the pattern of predictor variables in the present study was not typical of that found in hearing children because chronological age was the main determinant of reading and spelling ability. However, this is not surprising given that the hearing children had virtually identical reading and chronological ages. Such was the extent of the age effect (prior to it being statistically controlled), that little variance remained to be accounted for. This could explain why even phonological awareness was not found to be a significant predictor, despite it being consistently reported as one of the strongest predictors of reading achievement in hearing children (for reviews see Goswami & Bryant, 1990; Wagner & Torgesen, 1987). Interestingly, the rime phonological awareness scores did explain an additional 8% of variance, over and above the effects of age, in performance on the spelling task.

Why are productive vocabulary and speechreading important for reading ability in deaf children? Given the specific nature of the vocabulary knowledge that was measured, it appears reasonable to infer that the most plausible explanation lies in the fact that it is easier to read a word that is already in one’s vocabulary (Vellutino, Fletcher, Snowling, & Scanlon, 2004). This appears particularly pertinent for reading in a relatively opaque orthography such as English where word-specific knowledge is required to read exception words such as “chaos.” An alternative explanation is that good semantic knowledge can provide a compensatory mechanism for children who have poor phonological skills (see Nation & Snowling, 1998; Snowling, Gallagher, & Frith, 2003). Several authors have argued that deaf children experience such severe delays in reading achievement because they are doubly penalized as they have problems with both top–down and bottom–up processes (King & Quigley, 1985; Marschark & Harris, 1996; Webster, 1988). However, it may be that those deaf children with relatively good semantic knowledge are not penalized to the same extent and can use this knowledge to compensate in some way for the comparatively poor phonological coding skills usually observed in deaf children. In comparison to the former explanation, which is equally plausible for the relationships observed between vocabulary and single-word reading and vocabulary and sentence comprehension, the latter explanation is more tenable for the stronger predictive relationship found with sentence comprehension where greater levels of vocabulary knowledge could help elicit word meanings from context.

Turning our attention to the strong relationship observed between speechreading skills and reading ability in the regression analyses, we can ask what deaf children might do with the information derived from speechreading, and why would it be important for reading development in a group of children from mixed language backgrounds? Many authors have suggested that speechreading forms the input on which a deaf child’s phonological code is based, and indeed, patterns observed in deaf children’s spelling errors and rhyme judgments have been found to be consistent with this hypothesis (e.g., Dodd, 1980; Dodd & Hermelin, 1977; Hanson et al., 1983; Leybaert & Alegria, 1995; Sutcliffe et al., 1999). If speechreading provides such a code for deaf children, is this code similar to the one that hearing children derive from speech, or could it involve a different coding strategy, possibly based upon articulatory gestures?

It has been argued that there is an abstract phonological code, which is not modality specific and which, therefore, could be derived from speech or speechreading (Alegria, 1996; Campbell, 1997; Dodd, 1987). Indeed, speechread information has been shown to be processed in a similar manner to auditory-presented information (Campbell & Dodd, 1980; Dodd, Hobson, Brasher, & Campbell, 1983). An alternative explanation is that, although deaf individuals do use a phonological code, it is qualitatively different to that used by hearing individuals (Campbell & Wright, 1989; Leybaert & Alegria, 1995; Lichtenstein, 1985) and possibly based upon articulatory contrasts
It would make sense that the code that deaf children derive from speechreading is based upon the articulatory gestures and motor movements. However, although this might suggest that deaf children develop a different code to that used by hearing children, this is not necessarily the case as it has been argued that speech is not a string of connected sounds but a string of coarticulated abstract phonetic elements that represent articulatory gestures and motor movements (Byrne & Liberman, 1999; Liberman, 1997, 1998). On this argument, deaf children develop a code that is fundamentally similar to that derived by hearing children from speech.

One final issue for comment is the significant effect of hearing loss. Many previous studies of reading in severely and profoundly deaf children have not reported a significant effect of hearing loss on reading (Dyer et al., 2003; Harris & Beech, 1998; MacSweeney, 1998; Waters & Doehring, 1990). However, two studies investigating reading achievement only in profoundly deaf individuals have observed such a relationship (Geers & Moog, 1989; Moores & Sweet, 1990). One possible explanation for the significance of the effect in our study is that, with the advent of better hearing aid technology, children with lower losses are at a greater advantage than those with higher losses because residual hearing is used more effectively. As noted in the introduction, previous research has been equivocal about the importance of the relationship between reading and phonological awareness in young deaf children although stronger relationships have been observed in older deaf adolescents (Campbell & Wright, 1988; Dyer et al., 2003). It is not clear whether any of the previous studies, which reported significant associations between phonological awareness and reading, controlled for hearing loss. If they did not, it is possible that the relationship between phonological awareness and reading could be mediated by hearing loss because in our study phonological awareness was only a significant correlate of reading ability if hearing loss was not controlled.

In conclusion, we have shown that both speechreading and productive vocabulary are important skills for reading achievement in deaf children from varied language backgrounds. Spelling was not related to any of the measures in the present study, apart from reading, suggesting that, although reading and spelling ability are related in deaf children, they are also fairly disparate skills as they exhibit different patterns of correlations. Longitudinal studies need to be conducted in order to determine the importance of speechreading and productive vocabulary knowledge for reading development and to investigate the apparent disparity between reading and spelling strategies, in deaf children.

Note

1. Before the effect of chronological age was statistically controlled, single-word reading and spelling ability showed a very similar pattern of relationships, whereby both were significantly associated with each other, speechreading, rime phonological awareness, and short-term memory. Sentence comprehension was significantly correlated with spelling ability and speechreading before the effects of age were controlled.

References


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