Deafness and Education International
Deafness Educ. Int. **11(4)**: 171–190 (2009)
Published online 11 November 2009 in Wiley InterScience
(www.interscience.wiley.com) **DOI**: 10.1002/dei.266

Phonological Awareness and Decoding Skills in Deaf Adolescents

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ABSTRACT

This study investigated the phonological awareness skills of a group of deaf adolescents and how these skills correlated with decoding skills (single word and non-word reading) and receptive vocabulary.

Twenty, congenitally profoundly deaf adolescents with at least average nonverbal cognitive skills were tested on a range of phonological awareness tasks, and a non-word and real-word reading task, and their speech intelligibility was rated. Scores on a receptive vocabulary measure were gathered from existing records. All participants met an inclusion criterion of scoring within one standard deviation of the mean on a non-verbal reasoning task.

As a group, compared to the hearing standardisation samples, the participants' single-word reading fell within the normal range; their non-word reading skills were significantly stronger and their phonological awareness skills and receptive vocabulary were significantly weaker. The participants' phonological awareness skills were relatively stronger at the level of the phoneme than the rhyme. Correlations between single word and non-word reading and phonological awareness skills were significant. Taking receptive vocabulary as a covariate, the association between word reading and phonological awareness was reduced but remained significant, but the association between non-word reading and phonological awareness became non-significant.

The participants had developed good grapheme-phoneme knowledge in spite of relatively weak phonological awareness skills. This study is not able to inform whether this has occurred because only a minimal level of phonological awareness is necessary for grapheme-phoneme skills to develop or whether the process of learning to read has led to the development of grapheme-phoneme and phonological awareness skills, but ideas for future research are discussed. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: phonological awareness, decoding, reading, receptive vocabulary, deaf adolescents

INTRODUCTION

Phonological awareness (PA) refers to the awareness of and access to the sound structure of a language (McBride-Chang, 2004) and involves metalinguistic skills. Tasks designed to measure PA differ in terms of the 'level' of PA that is being measured (syllable, rhyme, or phoneme). The demand of a task is also different according to the type of activity employed and whether it involves recognition/forced choice, generation of items, or manipulation of items. PA has attracted much research attention as it has been found to be correlated with reading ability in hearing children (see Goswami and Bryant, 1990, for a review), predictive of later literacy skills (Bryant, 1991), impaired in children who have significant literacy difficulties (Dodd et al., 1995; Pratt and Brady, 1988) and poor in children with speech delays and disorders (Dodd et al., 1995). Given its link with literacy skills and the fact that many hearing-impaired children experience significant problems acquiring adult literacy levels (Chamberlain and Mayberry, 2000; Conrad, 1979; Gregory, 1995; Traxler, 2000), the PA skills of hearing-impaired children have also been studied (Campbell and Wright, 1988; Charlier and Leybaert, 2000; Hanson and McGarr, 1989; Harris and Beech, 1998; Harris and Moreno, 2006; Palmer, 2000; Sterne and Goswami, 2000; James et al., 2005; Waters and Doehring, 1990). Clearly, the question of whether PA is necessary for learning literacy has important implications regarding how young children and those with specific literacy difficulties should be taught. Research on the relationship between PA and reading in the deaf population is limited, particularly amongst children whose reading skills are in line with the reading skills of hearing children of the same age. The current study examined decoding abilities, as measured by single word and non-word reading tasks and PA skills in a group of profoundly deaf adolescents who attended a residential school for hearing-impaired youngsters which selects its students for their potential to achieve the UK national standard achievement in terms of public examination passes at 16 years of age.

Reading skills

The simple model of reading describes two related but separable skills: first, those involved in 'cracking the code' or acquiring the alphabetic principle, and second, those concerned with reading for meaning (Gough and Tunmer, 1986). The focus of this study is on the first component, the 'decoding skills', as measured by reading accuracy which involves translating written symbols that constitute words into the sounds of spoken language.

In a detailed review of the literature, Castles and Coltheart (2004) concluded that while PA and reading accuracy are undoubtedly correlated in

DOI: 10.1002/dei

hearing children, there is no unequivocal evidence of a causal link from competence in PA skills to success in reading and spelling acquisition. Some researchers believe that the relationship between PA and reading shifts from a causal one to mutual facilitation (e.g. Ball, 1996). Others state that higher level PA skills, such as phoneme manipulation, emerge later as a result of reading instruction (Gallaher, 1995; Share, 1995).

PA and deafness

The development of PA skills is difficult for deaf children due to their limited ability to perceive speech. Lip patterns cannot give all of the information contained within the speech signal and many deaf individuals are not able to access all of the acoustic cues necessary to perceive a difference between many speech sounds (Binnie et al., 1974; Erber, 1979; Leybaert, 1992). If PA skills are essential prerequisites for reading acquisition, it follows that deficits in these skills may underpin the poor reading performance of deaf children.

Studies into the development of PA in deaf children have yielded some differing results regarding how PA develops in this population and which factors influence the development of these skills (e.g. Harris and Beech, 1998; Locke, 1978; Miller, 1997; Quinn, 1981; Sterne and Goswami, 2000; Transler et al., 1999). The deaf population is heterogeneous in terms of hearing loss, how the hearing loss is aided, first language (British Sign Language, English, etc.), non-verbal ability, speech reading ability and language skills and these are all variables that might account for individual differences in performance on PA tasks. Also, different methodologies have been adopted. For example, task administration varies, including the use of spoken language (e.g. Dodd and Hermelin, 1977), written language (e.g. Hanson and McGarr, 1989), picture-based tasks (e.g. Campbell and Wright, 1988) and the use of sign to back up the spoken or written word (e.g. Hanson et al., 1983). It is very possible that when PA tests are administered via different modalities the set of skills tested is different bringing into question whether some of the skills measured within the deaf population are actually comparable to those reported for hearing children. Studies have measured different aspects of PA, for example, Campbell and Wright (1988) assessed rhyme judgement and Olson and Nickerson (2001) probed syllable awareness.

PA and deaf adolescents

Examining the PA skills of deaf adolescents is interesting, as it shows what development is possible with time. Evidence suggests that syllable awareness has developed in most deaf adolescents (Olson and Nickerson, 2001; Sterne and Goswami, 2000). Studies show that although rhyme awareness does develop to some extent in this age group, it is not necessarily to the same level as that of reading or chronological-age controls (Campbell and Wright, 1988; Charlier

DOI: 10.1002/dei

and Leybaert, 2000; Dodd and Hermelin, 1977; Hanson and Fowler, 1987; Hanson and McGarr, 1989; Sterne and Goswami, 2000). The evidence on deaf adolescents' use of a phonological code when reading and spelling is mixed. Quinn (1981), Hanson et al. (1983, 1991) and Burden and Campbell (1994) reported positive results. Locke (1978), Dodd (1980) and Waters and Doehring (1990) failed to find evidence that deaf adolescents are reading or spelling using a phonological code.

One study of deaf adolescents (Campbell and Wright, 1988) and two studies of younger deaf children (Hanson et al., 1984; Harris and Beech, 1998) have reported correlations between reading age and some aspects of PA. Harris and Moreno (2006) found that PA was significantly associated with reading abilities only if the level of hearing loss was not controlled. Palmer (2000) found that teaching PA skills and grapheme-phoneme knowledge to two deaf children improved both their PA and reading scores. There is other evidence that teaching phonics skills (i.e. direct teaching about the relationship between the sounds of the language and the letters used to represent these sounds) leads to improvement in reading skills in deaf children (Trezek and Malmgren, 2005; Trezek and Wang, 2006). There is no study available that investigates the impact of teaching *only* PA (whether at pre-school level or subsequently) on reading success in hearing-impaired participants.

Other skills have been found to correlate with the development of PA in deaf children including speech articulation (Campbell and Wright, 1988; Hanson et al., 1983, 1991; Hanson and Fowler, 1987; Sterne and Goswami, 2000), speech/lip-reading (Campbell and Wright, 1988; Dodd and Hermelin, 1977; Harris and Moreno, 2006; Kyle and Harris, 2006), the level of hearing loss (Conrad, 1979; Harris and Beech, 1998), intelligence (Conrad, 1979) and decoding skills (Dyer et al., 2003). In contrast, in one study, speech intelligibility (Harris and Moreno, 2006) and in another, rapid automatised naming (RAN) (Dyer et al., 2003) have been found to be unrelated to the reading skills of deaf children. Communication mode (manual/oral) has not been found to affect the development of PA (Miller, 1997; Quinn, 1981), although only low numbers were involved in these studies and not every aspect of PA was tested. Also, in a more recent study, strong positive correlations have been found between sign vocabulary and reading vocabulary (Hermans et al., 2008), although PA skills were not assessed in this study. Early exposure to cued speech has been found to enhance the development of PA (Charlier and Leybaert, 2000).

With the exception of Kyle and Harris' (2006) finding of a significant correlation between vocabulary levels and PA in their sample of seven- and eight-year-old deaf children, there has been no study published in which the correlation between language development and PA in deaf children is reported. Given the relationship between reading and language (see Beck and Olah, 2001) and the linguistic nature of PA skills, it is possible that a participants' understanding of English does relate to his/her PA ability. In a recent study of

DOI: 10.1002/dei

hearing children, Ouellette (2006) investigated the different areas of vocabulary (receptive and expressive vocabulary breadth and depth of vocabulary) and how these relate to different aspects of reading skills (decoding, visual word recognition and reading comprehension). For the hearing grade 4 students tested, receptive vocabulary breadth predicted decoding performance after controlling for age and non-verbal intelligence. This study did not investigate any PA skills and Ouellette (2006) acknowledges that if phonological-processing skills had been measured and controlled for the variance in the different aspects of reading attributed to vocabulary breadth may not have been as substantial. In Kyle and Harris' (2006) study, vocabulary was found to be a significant predictor of reading skills in their younger deaf sample of children.

Aims of this study

This study examined the PA skills of 20 deaf adolescents with at least average nonverbal cognitive skills using standardised materials. The study aimed to:

1. Investigate the range of decoding skills in the sample as measured by accuracy of reading single words and non-words.
2. Compare participants' mean word reading and non-word reading performance with that of their hearing peers (on whom the tests were standardised).
3. Investigate the range of PA skills at the rhyme and phoneme levels.
4. Compare the participants' mean PA performance with that of their hearing peers using standard scores derived from the hearing population.
5. Consider the relationship between the participant's performance on real-word reading, non-word reading and scores obtained from PA tests.
6. Consider the extent to which this relationship is explained by variance in receptive vocabulary breadth.

METHOD

Participants

The 20 participants attended a selective oral/aural, boarding secondary specialist school for deaf pupils in the UK. The school selects students with the potential non-verbal ability to attain the UK national standard achievement for 16-year olds in public examinations. All participants met an inclusion criterion of a nonverbal score within one standard deviation (SD) of the mean (≥7) on the Matrix Reasoning subtest of the Weschler Advanced Scale of Intelligence (WASI) (Psychological Corporation, 1999). The sample had a mean nonverbal score of 11.35, SD = 2.18, minimum = 7, maximum = 16. The sample was fully representative of the children in school years 7–9 at the school who fulfilled the selection criteria: all parents who were approached gave

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Table 1: Distribution of subjects by year group according to hearing status of family and the adolescents' first language.

Year Group	Mean age	Number	Family		First language	
			Deaf	Hearing	BSL	English
7	11 (y); 11 (m)	6	6	0	5	1
8	12 (y); 10 (m)	7	4	3	3	4
9	14 (y); 3 (m)	7	1	6	5	2
Totals		20	11	9	13	7

BSL = British Sign Language.

consent (see Table 1). All participants were born profoundly deaf (i.e. have an average loss of at least 95 dB at threshold levels of 250, 500, 1000, 2000 and 4000 Hz in their better ear, (British Association of Teachers of the Deaf, 2001) and are aided with digital hearing aids. The mean age of the participants was 13 years (SD = 12 months, range 11 years 2 months — 14 years 1 month) and three quarters (n = 15) were boys. Table 1 shows how the participants were distributed over the three year groups and gives information regarding family background and first language.

Procedures

Each participant underwent approximately 90 min of formal testing in a quiet room in the school, in two or three testing sessions. The session began with an explanation of the study and each student read and signed an information and consent form. The formal assessments were administered in the following order: Basic Reading Sub-test of the Weschler Objective Reading Dimensions (WORD), Matrix Reasoning sub test of the WASI and the Phonological Assessment Battery (PhAB). All standardised reading, language and PA assessments had mean scores of 100, SD = 15.

Assessments

Word and non-word reading ability

Word reading was measured using the Basic Reading subtest of the WORD (Rust et al., 1993). non-word reading was assessed using the non-word subtest of the PhAB (Frederickson et al., 1997). This assessment consists of ten single-syllable non-words and then ten multi-syllable non-words, for example, 'pim', 'cromgat' and 'yutmip'.

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Nonverbal abilities

Nonverbal ability was measured using the Matrix Reasoning subtest of the WASI (Psychological Corporation, 1999). It is a non-verbal fluid reasoning and general intellectual ability task. The standard scores provided are based on a mean of ten and SD of three.

PA abilities

PA abilities were measured using the PhAB (Frederickson et al., 1997). This assessment, based on Frith's (1995) theoretical framework, comprises nine subtests (eight 'phonological' and one 'non-phonological'). Within this framework phonological-processing skills at the cognitive level are held to relate to differences in brain functioning, which are often genetic in origin. These phonological-processing abilities are manifested at the behavioural level as grapheme-phoneme knowledge, PA skills and RAN. The two RAN tests are not included in the analyses because RAN is seen as a measure of the accuracy and efficiency of retrieval of phonological information from the lexicon (Denckla and Rudel, 1976) rather than PA. However, the result of the non-phonological sub-test, semantic fluency, is given because it provides a measure of how this deaf sample compared to the hearing standardisation sample on a non-phonological task. The remaining subtests measure PA in different ways. For alliteration awareness and rhyme identification (rhyme ID) the subject has to listen to three different words and decide which begin with the same sound or rhyme (e.g. ship, fat, fox). The alliteration and rhyme fluency tasks require the subject to generate items using his/her phonological knowledge as quickly as possible (e.g. tell me as many words as you can that rhyme with 'more'). The spoonerisms task requires manipulation of items given at a phoneme level (e.g. cot with /g/ gives 'got' and King John gives 'Jing Kon'). The alliteration awareness subscale was excluded from the analyses due to ceiling effects on this task in the normative sample within this age range. The final phonological task is non-word reading (described above).

Speech intelligibility ratings

Participants' speech intelligibility for conversational speech was rated using the speech intelligibility rating scale (SIR) (Parker and Irlam, 1995), which was developed for use with deaf speakers. Ratings were carried out by the first author who was familiar with the speech of adolescents with hearing loss. The SIR is a 6-point scale, where 0 indicates the most intelligible speech and 5 the least intelligible.

Language

The results of the measures of the *British Picture Vocabulary Scales, Second Edition* (BPVS) (Dunn et al., 1997), which measures understanding of English

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vocabulary, were collected from the pupils' school records. All participants were assessed on this measure within the six months prior to the commencement of this study.

Modifications to standardised procedures

Assessments were administered initially according to instructions in the manuals. The three PhAB subscales (alliteration awareness, rhyme ID and spoonerisms) that were particularly susceptible to participants failing items because they experienced difficulty with the oral presentation were re-visited and presented in a modified form, using signs. It was not possible to present these items using the written word, or through the use of finger spelling as this would have given a clear clue to the answers where congruent words were used (e.g. which words rhyme: sail, boot, nail). Although the participants all attend an oral school, many had exposure to basic sign in the past and also see sign used socially. Nearly two thirds of the sample stated that sign was their preferred mode of communication (see Table 1).

Two new scores were generated, combining some of the phonological subtests to create an overall measure of phonological ability, when items were presented with and without sign. The phonological total without sign variable includes the combined standard scores (standard scores were summed and divided by four) of rhyme awareness (standard administration), spoonerisms (standard administration), alliteration fluency and rhyme fluency. The phonological total with sign variable includes the combined standard scores (standard scores were summed and divided by four) of rhyme awareness (signed administration), spoonerisms (signed administration), alliteration fluency and rhyme fluency.

Data analysis

Analyses reported were undertaken using the Statistical Package for the Social Sciences, Version 14 (SPSS, 2007). All statistical tests used were two-tailed and an alpha of 0.5 was adopted (unless stated that a correction was applied for multiple comparisons). The one-sample Z test was used to compare the mean performance of the sample with the average performance of hearing children from the standardisation samples of the same age, as both the population means and SDs were known (Pring, 2005). Paired sample t-tests were used to compare participants' repeated performance on tasks using standardised and modified procedures as described above and univariate analyses of variance (ANOVAs) were adopted for between group comparisons. Pearson product-moment correlations were used to measure the strength of the relationships between key variables.

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RESULTS

Comparison of the performance of the three year groups on key measures

Table 2 shows means and SDs for the key variables: word reading and PA, language covariate and inclusion variable, and nonverbal ability, as measured on the Matrix Reasoning subtest of the WASI (Psychological Corporation, 1999), across the three year groups.

Despite some variation across the three year groups in mean scores, with a tendency towards lower scores in the oldest group, none of the year-group differences in performance on the key variables or language covariate were significant (F_{WORD} (2,17) = 0.78, p = 0.5; F_{PA} (2,17) = 1.77, p = 0.2; F_{BPVS} (2,15) = 1.15, p = 0.3). For ease of presentation the modified scores (which include items passed when presented using sign) only are presented in Table 2, but no significant difference across the year groups in PA taking the standardised rather than modified scores was found (F_{PA} (2,17) = 0.7, p = 0.51). In contrast, the year-group difference in non-verbal ability (NVIQ) was significant overall (F_{NVIQ} (2,17) = 3.86, p = 0.04), although none of the post-hoc comparisons made between the different year groups emerged as significantly different. As the differences on the remaining tasks were non-significant, the year groups were combined and treated as a single group (n = 20) in the subsequent analyses.

Comparison of the deaf sample with the hearing standardisation samples

Table 3 shows descriptive statistics for performance on the reading tests, the PhAB sub-tests and composite score, the BPVS and the SIR. Results of the modified presentations for the two PhAB tests and the derived composite PhAB score are presented in the main body of the table and the results of the standardised procedures are given in italicised parentheses.

Table 2: Means and standard deviations on non-verbal, reading, total phonological awareness and receptive vocabulary tasks for year groups 7, 8 and 9.

Year group	n	Non-verbal		Word reading		PA*		BPVS	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
7	6	13.2	1.9	100.3	10	91.3	9.8	73.4	25.3
8	7	10.6	2	101.9	12.2	89.0	9.4	80.7	18.2
9	7	10.6	1.7	93.9	14.8	82.4	7.9	61.8	24.6

*Modified scores. PA = Phonological awareness; BPVS = British Picture Vocabulary Scales; SD = standard deviation.

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Table 3: Means, standard deviations, and maximum and minimum standard scores for word and non-word reading ability, phonological awareness performance, receptive vocabulary and speech intelligibility.

Measure	Mean	SD	Maximum	Minimum
Reading				
Word	98.6	12.48	73	120
non-word	113.55	13.4	88	128
PA				
Rhyme	86.8 *(77)*	14.49 *(8.76)*	69 *(69)*	124 *(101)*
Spoonerisms	93.25 *(85.55)*	12.84 *(16.73)*	76 *(69)*	127 *(127)*
Alliteration fluency	87.9	12.07	69	108
Rhyme fluency	81.6	13.87	69	117
Total PA	87.39 *(83.01)*	9.41 *(9.42)*	74 *(72)*	106 *(104)*
Receptive vocabulary				
BPVS	72.39	22.66	40	113
Speech intelligibility				
SIR	3.15	1.23	1	5

Figures are based on a total sample of n = 20 for all measures. Results of the modified presentations for the Phonological Assessment Battery are given in the main body of the table and results of the standardised procedure are given in italicised parentheses. SIR = Speech intelligibility rating scale. Other abbreviations are given in Table 2.

Paired sample t-tests showed that the way in which these subtests were administered significantly affected the groups' scores on each test (rhyme ID: $t(19) = -3.48$, $p = 0.003$, $\eta^2 = 0.39$; spoonerisms: $t(19) = -3.60$, $p = 0.002$, $\eta^2 = 0.41$; PA total: $t(19) = -4.26$, $p < 0.001$, $\eta^2 = 0.49$). The modified procedure affected performance on the two PhAB tasks in different ways: raising lower scores on the spoonerism test and increasing the range of the upper scores on the rhyme task (Table 3). Interestingly, the modified procedure significantly improved performance of the signers (n = 13) on the spoonerism task, but had no effect on the scores of the non-signers (n = 7), $F_{interaction}(1,18) = 10.49$, $p = 0.005$ (signers, $mean_{with} = 90$, $SD_{witth} = 9.7$; $mean_{without} = 78.15$, $SD_{without} = 11.81$; non-signers, $mean_{with} = 99.29$, $SD_{witth} = 16.39$; $mean_{without} = 99.29$, $SD_{without} = 16.39$). A similar trend was found for rhyme, but in this case the interaction was non-significant, $F_{interaction}(1,18) = 2.19$, $p = 0.16$ (signers, $mean_{with} = 87.54$, $SD_{witth} = 15.09$; $mean_{without} = 74.77$, $SD_{without} = 6.17$; non-signers, $mean_{with} = 85.43$, $SD_{witth} = 11.36$; $mean_{without} = 81.14$, $SD_{without} = 11.67$). Where $F_{interaction}$ refers to the interaction effect between the condition (i.e. type of phonological task involved) and group membership (signers, non-signers).

Speech intelligibility

Intelligibility scores covered the full range, except none of the participants achieved the lowest score of 0. A higher proportion of the sample gained higher

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scores indicative of poorer levels of intelligibility. In line with Harris and Moreno's (2006) finding, no significant associations were found between intelligibility ratings and word reading ($r = -0.16$, $p = 0.5$) or non-word reading ($r = 0.08$, $p = 0.73$). The intelligibility ratings were excluded from subsequent analyses.

Reading

The means, SDs, and minimum and maximum scores for the deaf subjects' performance on the WORD basic reading test and non-word reading test are shown in Table 3. The mean score on the WORD reading was close to the standard mean score of 100 and a one-sample Z test showed that there was no significant difference between the performance of the deaf participants and the hearing standardisation sample on this assessment ($Z = -0.42$, $p = 0.34$). The range of scores was wide, and the lowest score fell more than two SDs below the mean. In contrast, *all* the participants performed in the average range on the non-word reading test, and the mean non-word reading score was significantly higher than their mean score on the word reading task ($t(19) = -5.02$, $p < 0.001$). A one-sample Z test showed that the deaf participants performed significantly better than the hearing standardisation sample on the non-word reading subtest ($Z = 4.04$, $p < 0.001$) (see Figure 1).

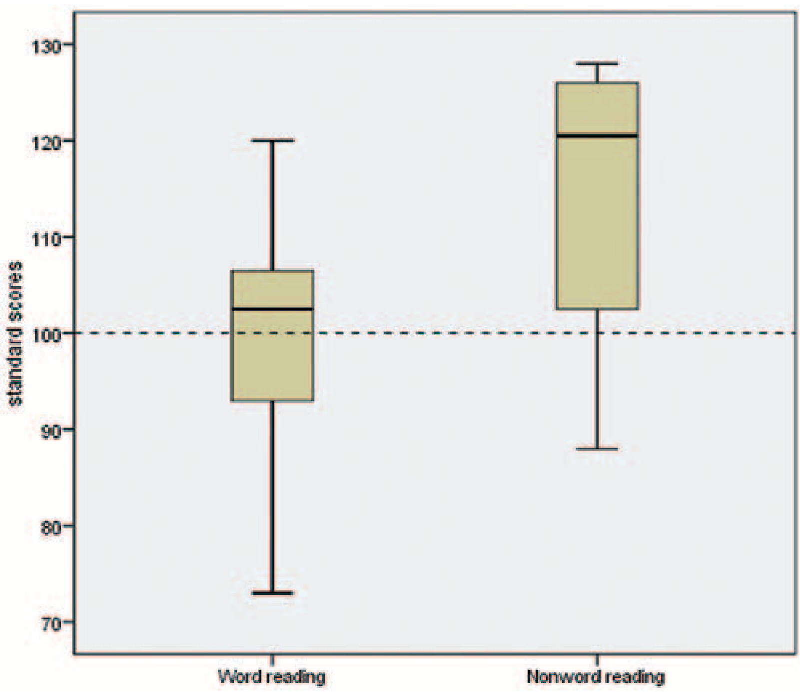

Figure 1: Box plots to show standard scores on the real and non-word reading tasks.

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PA skills

Table 3 shows descriptive statistics for each of the total PA scores when calculated without and with signed administration scores on rhyme ID and spoonerisms. One-sample Z tests showed that the deaf subjects performed significantly more poorly than the hearing standardisation sample for the total PA score without sign ($Z = -5.07$, $p < 0.001$) and the PA score with sign ($Z = -3.76$, $p = < 0.001$).

Table 3 shows descriptive statistics for each of the subscale scores that comprised the total PA score. The standard scores on the rhyme ID subtest were, in part, kept low because of a ceiling effect. The maximum standard scores that could be obtained were 124 for 12-year olds, 122 for 13-year olds and 118 for 14-year-old subjects. The majority of scores for this task fell below the mean, so it is likely that the overall impact of ceiling effects was minimal.

One-sample Z tests showed that the deaf participants performed significantly more poorly than the hearing standardisation sample for all subtests, as follows: Rhyme ID oral ($Z = 6.88$, $p < 0.001$), Rhyme ID signed ($Z = 3.94$, $p < 0.001$), Spoonerisms oral ($Z = 2.01$, $p < 0.001$), Spoonerisms signed ($Z = 2.01$, $p < 0.05$), Alliteration fluency ($Z = 3.61$, $p < 0.001$) and Rhyme fluency ($Z = 5.94$, $p < 0.001$). Bonferroni's correction for multiple comparisons was applied, which reduced the alpha level to 0.01 and the difference on the Spoonerism signed task was no longer significant. A repeated measures ANOVA showed that the group performance varied significantly across the subtests ($F(3,57) = 3.83$, $p = 0.02$), based on the modified presentations. A post-hoc comparison, adopting Bonferroni's correction for multiple comparisons, revealed significantly higher performance on the spoonerisms task compared with the rhyme production task ($p = 0.003$).

Non-phonological PhAB sub-test

Table 3 shows descriptive statistics for the semantic fluency sub-test of the PhAB. This task was included as a measure of a non-phonological skill. In contrast to the phonological tasks, the performance of the deaf participants on the semantic fluency task did not differ from the hearing population ($Z = -0.88$, $p = 0.2$).

Language skills

Table 3 shows descriptive statistics for the BPVS. A single-sample Z test showed that when compared with hearing controls, the deaf performed significantly more poorly than the hearing standardisation sample $Z = -8.23$, $p < 0.001$.

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Table 4: Intercorrelational matrix showing correlations between word reading, non-word reading, phonological awareness and receptive vocabulary.

Measures	1. Word	2. Non-word	3. PA
1. Word reading	1		
2. Non-word reading	0.47*	1	
3. PA	0.81*** *(0.73***)*	0.57** *(0.48**)*	
5. BPVS	0.74*	0.43	0.86*** *(0.91***)*

For all correlations, n = 20. Asterisks denote significance values: *0.05, **0.01, ***0.001 (two-tailed). Results of the modified presentations for the Phonological Assessment Battery are given in the main body of the table and results of the standardised procedure are given in italicised parentheses. Abbreviations are given in Table 2.

The relationship between word reading, PA and language

Correlations and partial correlations were used to explore the relationships between the independent variables, and are displayed in Table 4. As for Table 3, results of the modified presentations for the PhAB tests and the derived composite PhAB score are presented in the main body of the table and results of the standardised procedures are given in italicised parentheses.

The size of the sample precluded entering all of the variables into a single multiple regression analyses (Tabachnick and Fidell, 1996).

All correlations reached significance except for the relationship between non-word reading and BPVS that fell just short of significance ($p = 0.06$). The correlation between word and non-word reading was significant and accounted for just over a fifth of the common variance. The correlations between word reading, PA and BPVS were higher than the corresponding correlations between non-word reading and the same measures. Given the high correlations between PA and BPVS, one possibility is that the correlations between the single word and non-word reading and PA can be explained by their associations with performance on the BPVS. Taking BPVS scores as a covariate, the association between word reading and PA (modified) was reduced but remained ($r = 0.52$, $p = 0.02$), but the association between non-word reading and PA became non-significant ($r = 0.44$, $p = 0.24$).

DISCUSSION

To the best of our knowledge this is the only study of reading skills in the deaf population to exclusively target adolescents of at least average non-verbal cognitive ability and who have word reading skills that fall within the average range when compared to those of their hearing peers. This group was educated in a high-achieving specialist school, and more than half were children of deaf parents (compared with less than ten per cent in the general population,

DOI: 10.1002/dei

Mitchell and Karchmer, 2004). The study is also unique in adopting PA measures that were standardised on samples of hearing children. Some procedural modifications were introduced, but the stimuli themselves were unchanged and the findings from the study allow some direct comparisons to be made with the performance of age-matched hearing peers. The study is informative regarding PA skills, real and non-word reading abilities amongst the deaf and more generally, in terms of the ongoing debate on the relationship between PA and reading.

Real and non-word reading

Despite nonverbal cognitive skills in at least the average range, the basic word reading test revealed a wide range of reading abilities, including three scores which were more than one SD below the mean. Nonetheless, the average mean performance of the sample did not differ from the mean performance of their hearing peers. In contrast, *all* the youngsters' decoding skills, as measured by their performance on the non-word reading test, fell in the average range or higher, and their overall performance was better than the average non-word reading skills of their age-matched hearing peers and superior to their own word reading skills. Their marked competence in decoding skills, in contrast to Sterne and Goswami's (2000) findings for younger deaf children with a mean age of 11 years, may partly be a function of different methodologies. Sterne and Goswami (2000) used a procedure where their participants had to choose a homophone to match a pictured item from a series of nonsense words (e.g. to pick 'boiz' for a picture of two boys). This difference may also reflect differences between the groups of children studied in past teaching methodologies. Intensive training in grapheme-phoneme correspondence has been found to foster decoding ability in young hearing children at risk of reading problems (Bowyer-Crane et al., 2008) and to boost the reading skills of deaf children (Palmer, 2000; Trezek and Malmgren, 2005; Trezek and Wang, 2006). Unfortunately, there is no information available either in Sterne and Goswami's (2000) paper or for the participants in the present study on the type of instruction they have received in the past. In a review of reading research for deaf and hard of hearing, Schirmer and McGough (2005) found a dearth of research evaluating the effectiveness of phonological instruction and recommended investigation of the instructional practices found to be effective with normally achieving and disabled readers.

The participants' word and non-word reading skills were associated. This is in keeping with evidence that suggests that good deaf readers access reading through decoding and phonological skills (Burden and Campbell, 1994; Hanson et al., 1991; Quinn, 1981). The disparity between the youngsters' word and non-word reading scores is in line with studies that have reported regularity effects in reading and spelling amongst deaf youngsters and young adults (Burden and Campbell, 1994; Hanson et al., 1983, 1991).

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PA

Despite the fact that the scores of the participants' were either comparable to or stronger than the hearing standardisation sample on real and non-word reading, non-verbal reasoning and the non-phonological semantic fluency task, as a group the participants' scores on the PA tasks were significantly poorer than those of the hearing standardisation sample. This was the case whether tasks were administered purely through spoken language or with the addition of sign support to aid decoding of the stimuli. The directionality of the association between reading and PA in the hearing population is still debated (Castles and Coltheart, 2004) and the current findings question the extent to which these adolescents' reading skills were mediated by or dependent upon PA skills. Although the correlation between PA and reading ability was high, the participants' PA skills were much less well developed than their decoding skills and significantly poorer than the PA skills of their age-matched peers. These participants did not need age-appropriate PA skills in order to develop age-appropriate single-word reading skills.

This study cannot confirm whether a certain level of PA is necessary for reading to develop or whether the PA skills demonstrated by the participants were, in fact, boosted to the levels that they were by their decoding and reading ability. In Frith's (1995) model, grapheme-phoneme translation skills are indirectly affected by phonological-processing skills: non-word reading differs from pure tests of PA because it is only directly affected by the underlying skills of grapheme-phoneme knowledge and general intellectual abilities. The deaf participants in this study have developed good grapheme-phoneme knowledge in spite of relatively weak phonological awareness skills. One possible explanation is that during the process of learning to read these participants developed fluent grapheme-phoneme translation skills, which in turn have aided the development of their phonological-processing skills to the levels displayed in the study. Some support for this hypothesis can be found in Kyle and Harris' (2006) finding that PA skills in younger deaf readers developed to a significantly greater extent compared with age-matched hearing children during the process of learning to read. However, they also reported significant correlations between PA and reading from an earlier age for both hearing and deaf children. In this sample, there was no evidence that PA skills improved across the three age groups studied. A longitudinal study of a substantial sample of able, profoundly deaf children in which basic word reading, non-word reading and PA skills (at the level of the syllable, rhyme and phoneme) are measured from the beginning of school until secondary-school level would inform this important issue.

In keeping with other studies of deaf youngsters, the performance of these good readers on rhyme awareness tasks was particularly impoverished (Charlier and Leybaert, 2000; Dodd and Hermelin, 1977; Hanson and Fowler, 1987; Hanson and McGarr, 1989; Sterne and Goswami, 2000). The participants performed more poorly on rhyme awareness than they did on the spoonerisms

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task, which could be seen as a more challenging task, demanding segmental and phonemic skills. This finding is interesting because it provides some evidence that the participants' PA skills are relatively stronger at the phoneme rather than the rhyme level. This would not be expected in younger hearing children in whom syllable and onset-rhyme awareness usually develops prior to phoneme awareness (Gipstein et al., 2000; Goswami and Bryant, 1990; Trieman and Zukowski, 1991), but may be as a result of training that they have received, such as grapheme-phoneme training, possibly including some form of visual phonics (see Trezek and Malgren, 2005). There is already evidence that such explicit training boosts word reading skills in deaf children (Palmer, 2000; Trezek and Malmgren, 2005; Trezek and Wang, 2006). It is suspected that in the present study such training has boosted the participants' decoding skills and PA at the level of the phoneme, but not at the level of the rhyme. There is evidence that for hearing children, phoneme awareness is very strongly linked to explicit reading instruction (e.g. Huang and Hanley, 1995) and may not develop at all in languages, such as some dialects of Chinese (see Holm and Dodd, 1996; Read et al., 1986) where this type of awareness is not necessary in order to read.

Receptive vocabulary

The receptive vocabulary skills of the participants were also measured because of positive correlations cited between receptive vocabulary and decoding skills in hearing children (Ouellette, 2006) and between productive vocabulary, reading skills (as measured by single-word recognition and sentence comprehension) and PA (as measured by alliteration and rhyme similarity judgements) in deaf children (Kyle and Harris, 2006). As was expected, the participants' receptive vocabulary scores were significantly lower than those of the hearing standardisation sample. Receptive vocabulary was significantly correlated with real-word reading and PA scores, but its relationship with non-word reading fell just short of significance. When the effect of receptive vocabulary was partialled out the correlation between word reading and PA was reduced but remained significant, suggesting that receptive vocabulary, at least as measured by the BPVS, accounted for some but not all the shared variance between real-word reading and PA. This shared variance could be due to the participants' capacity to access the phonological representations of words and the breadth of their vocabulary of spoken word forms, both skills which should theoretically enhance the decoding of real words, receptive vocabulary and PA.

Caveats

Two caveats need to be considered. Some of the subjects had unintelligible speech when talking generally, but all had much clearer speech when

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articulating single words that they were reading. These students were educated and receive an oral environment and receive help with speech production if needed. Most of the assessment items required one-word responses and deaf speakers are usually able to produce single words in isolation more clearly than connected speech (Parker and Irlam, 1995). Secondly, this study was based on a relatively small sample of 20 adolescents, which limits the power of the analyses and type of statistical tests performed. However, the deaf population as a whole is small and heterogeneous and within this population of able, profoundly deaf good readers the participants tested were fully representative of youngsters within years 7–9 of the school who fulfilled the selection criteria.

CONCLUSIONS

The hearing-impaired participants in this study had developed age-appropriate basic and non-word reading skills, in spite of their PA skills being significantly delayed when compared to those of their hearing peers. This study raises interesting questions regarding the role of grapheme-phoneme awareness and training in the acquisition of literacy amongst deaf readers, and the role of PA in the development of decoding skills. Findings from the current study offered relatively little support for PA skills being essential prerequisites, but a longitudinal study is required to provide more definitive answers on the causal role of PA skills for reading competence in this population.

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