The Challenge of Learning to Read Written English for the Profoundly Pre-lingually Deaf Adult

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ABSTRACT

Many adults with profound prelingual deafness have difficulties reading and comprehending written English and this problem may originate from English phonological deficits and/or difficulties connecting sign language with written English. The purpose of this study was, therefore, to investigate the word coding strategies of profoundly deaf adults with a view to identify to what extent they used speech-based and sign-based strategies to process English text. For the gathering of the data participants completed three tasks: (1) a measure examining the use of speech and sign-based word coding during reading (2) a phoneme awareness task (3) and a task assessing skill in applying grapheme-phoneme correspondences. Data was analysed using tests of difference (t-tests and ANOVA) with the findings showing that while the less proficient readers had significantly greater English phonological deficits they reported only a minimal use of supplementary sign language coding strategies. Surprisingly, some of the proficient readers, with good English phonological skills chose to supplement them with some sign-based strategies. The possible reasons and instructional implications for these findings are discussed.

Keywords: phonological; adults; reading; deaf; sign-language

INTRODUCTION

Those adults with a profound hearing loss who have difficulty comprehending English text are often prevented from gaining access to further social, educational and employment opportunities. While profoundly deaf adults may experience frustration and failure most understand the need for English literacy skills. As well as being intimately linked to employment opportunities written English is frequently the only way they have to communicate with their hearing counterparts. The challenge of reading and understanding written text is seen by some as being linked to their profound hearing loss, language difficulties and some instructional practices (Clark et al. 2016, Herrera-Fernandez, Puente-Ferreras & Alvarado-Izquierdo 2014, Paul 2002). Profoundly deaf childrens' literacy skills generally lag behind their hearing peers (Rudner et al. 2015) and so a reading delay of six to eight years is not unexpected by the time they graduate high school (Mayberry, del Giudice & Lieberman 2010). Even at tertiary institutions, the average equivalent reading level is only at about the eighth grade (Bochner & Walter 2004), a fact of particular importance as literacy development for both deaf and hearing students is seen as critical for academic and workplace advancement (Furlonger & Rickards 2011, Zin, Wong & Rafik-Galea 2014).

While mastering written English is a lifelong struggle for many individuals with profound deafness a small but significant number have average and above average reading abilities (Walker, Munro & Rickards 1998, Traxler 2000). One hypothesis explaining the development of reading proficiency among those with profound hearing loss is that they were able to compensate for their reduced acoustic information with visible speech information derived from speakers' lip patterns facilitating the development of well-specified phonological representations needed for matching speech input to lexical patterns (Alegria 1998, Bernstein, Tucker & Auer 1998, Campbell 1998, Demorest & Bernstein 1992). Indeed, there is an assumption of 'functional equivalence' between visible speech information that a deaf person takes from the speech signal and that of a continuous phoneme stream that a hearing person gains through auditory-speech experience (Campbell 1997, McQuarrie & Parrila 2009). According to some researchers an individual with profound deafness does not gain access to the full range of meaningful phonological contrasts; thus the process of matching speech input to lexical patterns stored in memory becomes problematic (Kelly & Barac-Cikoja 2007). However, if a lack of fully specified phonological representations were the chief cause of reading difficulties then no individual with profound deafness would become a proficient reader (Belanger, Buam & Mayberry 2012, Herrera-Fernandez, Puente-Ferreras & Alvarado-Izquierdo 2014). This is clearly not the case, as about 10% of individuals who are deaf, become skilled readers (Traxler 2000). This number may also be increasing with the introduction of improved hearing technologies such as cochlear implants that provide meaningful access to spoken language for most recipients (Blamey, Barry, Bow, Sarant, Paatsch & Wales 2001).

A second hypothesis explaining the development of reading expertise argues that sign languages share enough similarities with spoken languages that they can be used as a bridge into the literacy of the majority language (Ewoldt 1996, Fischer 1995, Haptonstall-Nykaza & Schick 2007, Herrera-Fernandez, Puente-Ferreras & Alvarado-Izquierdo 2014, Puente, Alvarado & Herrera 2006) and might play a role, albeit small, in reading a speech-based written language such as English (Miller, Kargin & Guldenoglu 2015). Indeed, as sign language functions much like spoken language, language cannot just a by-product of articulatory/acoustic exchanges (Goldin-Meadow 2005). Ewoldt (1993) has proposed a 'top-down' model of reading comprehension whereby deaf readers are able to bypass auditory-based phonological decoding strategies, instead processing print by semantic cues. Relying on vocabulary and world knowledge, the comprehension of printed words is thus achieved by memorizing the visual representation of words that are then matched to the word in the existing vocabulary base. Potentially, some profoundly prelingually deaf people may be compelled to opt for non-phonological strategies as their hearing impairment obstructs an early and complete internalization of spoken language based on phonological knowledge, making the spontaneous use of phonological strategies in working memory problematic (Miller 2007).

Finally, a third hypothesis postulates that multiple coding strategies can be used to code an alphabetic language in order to overcome the limitation of any one strategy (Chamberlain & Mayberry 2000, Ross 1992). Ross (1992) found that strategies used by participants included; classifiers, gestures, sequences of fingerspelling followed by word signs and others spoke a word then signed it. Lichtenstein (1998) also found evidence for the use of multiple codes by deaf individuals when reading by using a short-term memory experiment that tested for the use of phonological, orthographic, sign and American Sign Language (ASL) fingerspelling encoding strategies. Interestingly, sign-based recoding decreased as the ability to make efficient use of speech-based recoding strategy increased. Even though it was common for the participants to combine codes only a few who used a sign-based recoding strategy had a reading ability above the ninth grade level.

In summary, the way in which a profoundly deaf adult may have learned to read is bound to be complicated (Hermans, Knoors, Ormel & Verhoeven 2008). In the first stage of development they may have; formed associations between written words and signs, using orthographic information without recourse to morphology or syntactic information, used sign language translation equivalences (lemma mediation) in the use of the written word, and used appropriate semantic, lexical, syntactic and morphological information for use within the lexical entry. For some the final stage would be characterised by the written word being strongly connected to the individual's conceptual system either directly or through links with the spoken language system (see Appendix 1).

Accordingly, it is the aim of this study to examine the coding strategies of Australian adults with prelingual profound deafness with a view to identifying whether proficient reading was linked to a preference for speech-based, sign-based or multiple coding strategies. The driving force behind such an investigation is the need to develop instructional practices that will assist in reading improvement for those profoundly adults who continue to struggle with comprehending written English.

The most commonly investigated modality for over 30 years has been the use of sound-based phonology in reading. There are studies that give evidence for phonological skills being used during reading by those who use sign and for those who use spoken language (Colin, Magnan Ecalle & Laybaert 2007, Harris & Moreno 2004, Khor, Low & Lee 2014), while others have found no evidence for the use of phonological skills during reading by the same two types of groups (Dyer, MacSweeney, Szczerbinski, Green & Campbell 2003, Waters & Doehring 1990). A possible explanation for such inconsistent results has been provided by the 'Multiple-coding hypothesis' of Hall and Bavelier (2010). They hypothesize that as many codes as possible may be used to maintain words in memory and that deaf readers may rely on codes more readily available to them. For example, orthographic, semantic, tactile, sign and fingerspelling codes may be used. Evidence for this hypothesis would suggest that phonological coding deficits are not at the core of reading problems for individuals with profound deafness. Indeed, in a study by Belanger, Baum and Mayberry (2011) skilled hearing, skilled deaf and less skilled deaf readers were tested to investigate the automatic use of orthographic and phonological codes during visual word processing and the use of both codes for maintenance of words in memory. Crucially, only skilled hearing readers used phonological codes while the skilled and less skilled deaf adults used orthographic codes during reading, leading the authors to conclude that deaf adults' reading difficulties may not have been linked to the activation of phonological codes during reading.

In line with this finding is evidence from a meta-analysis (Mayberry, del Giudice & Lieberman 2010) that experimentally tested for phonological awareness and coding among severely and profoundly deaf readers. Only 50% of the studies found the evidence for the use of phonological knowledge to be statistically significant. This result is surprising, as well-specified phonological representations have been considered important for reading development as they underlie phonological awareness skill, which is assumed to be a metalinguistic skill underpinning phonological recoding and reading development (Snowling & Hulme 2012). This set of skills is considered by many to be vital even for a prelingually profoundly deaf reader (see Perfetti & Sandak 2000). Without them the underlying representations of words are poorly specified and their lexical structures are not segmentally organised and available at the syllabic, onset-rime or phonemic level (Swan & Goswami 1997). However, there still remains some skepticism as to whether phonological awareness, on its own, is unequivocally directly causally linked to reading development although phonological awareness appears related to reading ability in some way (Dehaene 2009, Castles & Coltheart 2004).

Arguments proposing that sign skills can support the development of a functional 'soundless phonology' have been evaluated against the extent to which sign language is similarly able to support deaf individuals in the development of a lexical system of representation that in turn will support efficient written word reading strategies (Musselman 2000). There have been some studies demonstrating, that for deaf children, reading and writing ability was not based solely on their detailed knowledge of spoken English but rather their knowledge of the juxtaposition of ASL and English. Indeed, significant relationships have been reported between the use of initialized signs and reading for users of the North American one-handed alphabet (Clark et al. 2016, Ramsey & Padden 1998, Padden & Ramsey 1998). However, there is scarce research regarding whether Australian Sign

Language (Auslan) can effectively be used to process written words. Despite the lack of empirical research in Australia, a significant contribution to the theoretical understanding of how sign language can be used for reading has been made by Johnston (2002) who has detailed at least three ways in which Auslan can be connected to English print (for full review see Furlonger & Rickards 2011). First, the twenty-six hand configurations of Auslan fingerspelling that correspond with each letter of the English alphabet can be used to represent printed text. Second, users of Auslan can represent English words by *mouthing* words such as go, gone and went in combination with basic sign creating a *soundless phonology* made up of mouth articulations, lip and tongue configurations and the type of body resonance produced by vocal cords. Third, fingerspelling can be connected to English words by reducing the number of letters during fingerspelling (the letter *D* is repeated twice for daughter) and using the process of initialization. Initialization s sometimes used as an abbreviation technique during a sign language conversation instead of spelling the whole word.

In summary, previous studies have indicated that some readers with profound deafness may prefer speech-based, sign based or multiple coding strategies over speech-based coding. What support there was for multiple codes by readers with profound deafness came from North America and so it was not clear whether Australian adults would give evidence of the same forms of coding (both Australian Sign Language and American Sign Language exist in countries that have English as the majority language and yet are mutually unintelligible). The present study aimed to bridge this gap by examining whether adults with profound pre-lingual deafness would demonstrate a preference for predominantly speech-based, sign-based or multiple coding strategies when reading and whether their preference would be related to their reading comprehension ability. Using this research paradigm, the following hypotheses were formed: it was hypothesized that if reading ability was linked to the activation of speech-based phonological codes there would be a significant difference between proficient and less proficient readers on measures of phonological knowledge. It was also hypothesized that if the less proficient readers also had poorer speech-based phonological skills then they would report a greater use of sign-based or multiple coding strategies than the proficient readers.

METHOD

The 30 participants in this study all had profound pre-lingual deafness and were recruited through a capital city deaf society. To confirm their hearing loss participants were required to provide a recent audiogram or were tested with a standard audiometer if their audiogram was more than one-year-old. All had profound pre-lingual bilateral hearing loss, having an average unaided hearing loss of at least 90 dBHL in the better ear. The calculation was made by averaging the hearing loss at the following three frequencies: 500, 1000 and 2000 Hz. Table 1 shows the three frequencies used to calculate profound deafness for each participant and the average loss at each frequency.

TABLE 1. Mean hearing loss (dBHL), (SD) and range in the better ear of participants across three frequencies, and average loss overall

Loss at 500	*Loss at 1000*	*Loss at 2000*	*Mean loss*
94.5	105.3	112.5	104.3
(9.1)	(6.5)	(4.9)	(5.5)
80-110	90-120	100-120	95-104

It was not possible, for the purposes of reliability, to gather data from objective sources such as school records with respect to hearing aids nor was it possible to accurately estimate how effectively they used their residual hearing. While all had been fitted with hearing aids before the age of five most were no longer consistent wearers of hearing aids due largely to the prohibitive cost of replacement and repair (In Australia hearing aids are provided free only until the age of 21). Some only wore aids for specific purposes, such as driving a car. All participants were over 18 years of age, which is the legal age for adult classification in Australia. Ages ranged from 18 to 61 years with a mean age of 32. 7(SD = 12.9). Only adults were asked to volunteer, as they were considered more capable to reflect and report on their individual reading strategies.

All participants had completed high school and were either employed in fulltime work or enrolled in a tertiary institution were included in this study. No individuals had known additional intellectual, sensory or physical disabilities. All participants were from families in which spoken English was the 'primary' or first language, which meant that their early linguistic experience was exclusively spoken English. Exposure to sign language did not occur until they began school, and met other sign language users, although no academic instruction occurred in sign language. All but one of the participants had two hearing parents. The exception was a male participant who had a non-signing deaf mother. Despite this profile, only three participants relied entirely on spoken communication. The other 27 participants used sign language to varying degrees.

MEASURES

The Stanford Diagnostic Reading Test (SDRT) is a standardized reading comprehension test with 60 questions linked to reading tasks containing advertisements and narrative text (Karlsen, Madden & Gardner 1984). The highest SDRT level was used (e.g., Blue form G - Year 9-12). A non-standardized questionnaire originally published by Lichtenstein (1998) was adopted to investigate the extent to which participants used speech and sign coding during reading and writing. The validity of self-report measures for readers who are deaf has been established (Schirmer 2003, Schirmer, Bailey, Schirmer-Lockman 2004). The questionnaire was used in an interview format with points for their reported use of sign representations or speech-based coding for each task as determined by Lichtenstein.

Phoneme awareness was tested using a non-standardized task that contained 32 items based on 24 items published by Unthank and Goswami (2000) and Unthank, Rajput and Goswami (2001). The test was considered "fair" as it does not require a spoken prompt or a verbal reply, however, as yet there is no published data on reliability. Words were used that either forced the use of a phonological judgement or allowed orthographic knowledge to be used (see Appendix 2). The task required the participant to judge which word had the same first sound as the cue (cue: *three*, choice: *thumb*, distractor: *fork*) from word sets that had either the same or different spelling onsets. In all trials, the initial phoneme in the distractor word triplet differed by only manner, place, or voicing. This single difference was held constant in the 12 word triplets.

Grapheme-phoneme correspondence (GPC) was tested using a non-standardized task designed to assess whether participants could apply grapheme-phoneme correspondences and is identical to that published by Sterne and Goswami (2000). The participants were required to choose a non-word that sounded like a real word (*focs* for a picture of a fox). Three distractor non-words words were orthographically similar to the correct non-word homophone.

Non-Verbal I.Q (NVIQ) was assessed using the subtest "Matrix Reasoning" from the Wechsler Abbreviated Scale of Intelligence (1999). Table 2 displays the ages of participants in months and non-verbal intelligence (NVIQ) as percentiles. The two reading skill groups were matched on chronological age (CA) and NVIQ. The between group difference for age was insignificant, $F < 1$.

TABLE 2. Participant mean (SD) for age and NVIQ

	Chronological Age (months)	*NVIQ-percentiles*
Proficient readers	355.2 (159.4)	81.36 (20.57)
Less proficient readers	409.6 (162.9)	79.51 (15.63)

Language ability was established by using a five-point communication rating scale for both spoken and sign-language ability. Thus, participants were matched for general spoken and sign language ability only. As no formal or widely accepted Australian Sign Language (Auslan) language assessment instrument currently exists (Johnston, Leigh & Foreman 2002, Johnston 2004) the rating scales were informal and based on the South Australian Auslan assessment inventory, no standardized scores are available. Only individuals with a ceiling rating of five were included in the present study. There was no significant difference between the proficient and less proficient comprehension groups rated for sign language ability, ($t(15) = 1.00$, $p > .05$). There was also no significant difference between the proficient and less proficient comprehension groups rated for spoken language ability, ($t(11) = 1.97$, $p > .05$). Finally, the proficient and less proficient groups were compared on the 22 items common to both assessment-rating scales. There was no significant difference between the groups for this measure ($t(28) = 1.36$, $p > .05$).

PROCEDURE

Prior to testing, 17 of the 30 participants requested to have instructions using Auslan only. The 13 other participants asked to have the instructions and task information presented predominantly using spoken communication but occasionally supported with signs to aid clarity. Participants were provided with the opportunity to choose their interpreter of preference as this was seen to enhance their ability to understand instructions. An Auslan advisor was also used to assist in the selection of interpreters and to assist in the trialing of testing procedures. Following trials, 27 participants completed the experiments under the guidance of the first author and an interpreter. Three participants completed the experiments with the first author only. Participants completed all experiments in a quiet university room with standard florescent lighting.

The participants were asked to read eight reading comprehension passages, answer the six questions per passage within 40 minutes and to attempt every question. Following the delivery of instructions, no further assistance was provided.

For the word coding strategies participants were asked each of the questions using their preferred mode of communication. While each participant had a hard copy of the questionnaire, to which they could refer, all instructions were read to them using either spoken or sign language before the questions were discussed with the researcher. However, all responses were recorded by the examiner and checked with the Auslan advisor and interpreter. To aid understanding, questions were sometimes presented in different ways and discussed with the participant. For example, the question 'did you say the words to yourself?' was often used in conjunction with the question 'did you use speech inside?' In the reading and writing strategies tasks, six different paradigms were used to obtain information (long sentence, short passage, sentence writing, long sentence reading using alternative coding, questions prompting coding use and interpreting a sentence with a embedded relative clause). In each of these tasks, there was an analogous task or set of questions for speech and sign.

Scoring of the word coding strategies was completed according to that outlined by Lichtenstein (1998).

For phoneme awareness the participants were informed that the test was about words that had the same first sound. They were told that some deaf people could hear the sound, felt the sound on their lips when they spoke, or understood the sound in their mind. Examples were provided of words that had the same first sound when the first letter or letters were the same (*ship* and *show*, or *tiger* and *ten*). Other words, however, had the same first sound but have a different spelling as in *circle* and *sock*. Participants were told to be careful that words such as *sock* and *tank* have the same lip shape at the beginning of the word but do not sound the same (*sock* has a 's' sound and *tank* has a 't' sound). In the practice task, each of the participants was required to make five out of six correct initial phoneme judgements before moving onto the experimental task. All participants included in the experimental group successfully met these criteria.

For the grapheme-phoneme correspondence task the participants were shown a card with a picture at the top and four non-words underneath. Participants were asked to look at the picture, think of the word then match it with one of the words below. Participants were informed that the words were not real but sounded the same as a real word. They were asked to point at the non-word that matched the picture, and were given practice examples to demonstrate the purpose of the exercise. The first example did not show a picture, but the printed word 'please'. A non-word distractor *pleez* was required to be selected by the participant from words that included *gleez*, *ploz*, and *pleej*. The next three examples in the practice set used pictures to represent the real word of the picture.

RESULTS

The two reading ability groups that were formed on the basis of a medial split of their SDRT reading comprehension scores, proficient (n = 15) and less proficient (n = 15), had a significant between group difference, $t(28) = 8.88$, $p < .01$. The proficient group had a mean reading grade level more than twice that of the less proficient reading group. In addition, while seven members of the proficient group were reading above the 12th grade level none of those in the less proficient group was reading above the 7th grade. Overall, the less proficient group made more than three times as many errors as the proficient group with six scoring less than 50% correct. These data are displayed in Table 3.

TABLE 3. Group reading grade levels mean percent errors and range percent errors

	Reading grade levels	*Percent errors*	*Range (% errors)*
Proficient	10.71 (2.33)	15.5 (9.1)	5.0 - 30.0
Less proficient	4.93 (1.28)	46.7 (10.2)	33.4 - 61.7

Summary of research hypothesis one: The hypothesis that if reading ability was linked to the activation of phonological codes there would be a significant difference between proficient and less proficient readers on measures of phonological knowledge was met. Indeed, data from the phonemic awareness (PA) task demonstrated a significant effect of group, $F(1, 28) = 12.37$, $p < .01$, as well as a significant effect of spelling condition, $F(1,28) = 13.92$, $p < .01$, but no significant interaction, $F(1,28) = 2.06$, $p > .05$ (The summary statistics are shown in Table 4). The less proficient readers found the condition where they were forced to use a phonological strategy particularly challenging.

TABLE 4. Mean percent errors (SD) and reaction times for different and same spelling first sound matching phoneme awareness task

	Mean percent errors	
	Different spelling	Same spelling
Proficient	21.3(20.7)	5.4(5.7)
Less proficient	34.2(19.4)	12.1(12.1)

Similarly, in the grapheme-phoneme correspondence (GPC) task the less proficient reading group produced lower scores, with a significant difference between the two groups' ability to recode non-words, $t(28) = 2.74$, $p = .01$. The mean percent errors for the grapheme-phoneme recoding task (GPC) for both deaf groups are displayed in Table 5.

TABLE 5. Mean percent errors (SD) for the grapheme to phoneme correspondence (GPC) task

	Percent errors	Percent error range
Proficient	10.0 (16.9)	0 - 60
Less proficient	29.3 (21.5)	0 - 70

Summary of research hypothesis two: The hypothesis that if the less proficient readers also had poorer speech-based phonological skills then they would report a greater use of sign-based or multiple coding strategies than the proficient readers was met. However, only one of the less proficient readers reported an exclusive use of sign-based strategies and none of the less proficient group scored five or above for sign language coding. In contrast, only five of the proficient readers reported using some sign-based coding strategies and none exceeded a score of three. For the purpose of analysis participants were divided into two categories, participants who consistently used one or more of the modalities as against those who were inconsistent in the use of one or other of the modalities. In this instance, only scores of 5.0 and above were used to represent a consistent use of a modality to avoid classifying participants who occasionally thought of a sign for a word compared with those who used sign as a coding strategy, and those who may have misunderstood a question.

Overall, it was observed that 28 (93.3%) participants had scores on the speech-based word scale of at least 5.0. while 15 (26.6%) scored the maximum of 8.0. on the use of speech-based coding. Slightly less than half (14) of the participants reported using two modalities (speech and sign-based strategies). Summary data is displayed in Tables 6 and 7.

TABLE 6. Comparison of efficiency groups reporting the use of speech-based coding when reading

	Scores on combined speech-based scale (max 8.0)								
	8.0	*7.0*	*6.0*	*5.0*	*4.0*	*3.0*	*2.0*	*1.0*	*0.0*
Proficient	10	3	1	1	0	0	0	0	0
Less profic.	5	2	5	1	1	0	0	0	1

TABLE 7. Comparison of efficiency groups reporting the use of sign-based recoding

	Scores on combined sign-based scale (max 8.0)								
	8.0	*7.0*	*6.0*	*5.0*	*4.0*	*3.0*	*2.0*	*1.0*	*0.0*
Proficient	0	0	0	0	0	1	1	3	10
Less profic.	1	0	0	0	1	1	5	2	5

As additional calculation for the use of both speech-based and sign-based modalities were correlated with the GPC scores. Table 8 presents correlations of the speech and sign variables for combined memory and reading tasks. Speech-based coding was significantly positively related to grapheme-phoneme correspondence ability (.45), whereas working in a sign-based modality was negatively related to grapheme-phoneme recoding ability (-.50). It would appear that the participants reporting the use of a speech-based recoding strategy were more successful at matching letters with sounds.

TABLE 8. Inter-correlations for coding strategies and grapheme-phoneme correspondences

Variable	*Speech-based Coding*	*Sign-based Coding*
GPC	.45*	-.50*

*$p < .05$

Interestingly, over 80% of the less proficient reading group, despite their relatively poor phonemic awareness skills, still reported predominantly working in the phonological modality (speech-based coding). Indeed, about 30% preferred an exclusive speech-based code suggesting that, for this group at least, they were not reporting the use of multiple codes to overcome phonological deficits. To complicate an understanding of the role of multiple coding some of the proficient readers with good phonological skills reported using some sign-based coding. Whether they used such a strategy to connect with the orthography of printed words is uncertain.

DISCUSSION

The participants with more proficient reading comprehension skills also had superior phonological knowledge. This result, taken on its own, suggests that if less proficient profoundly deaf Australian readers were to improve their phonological speech-based word coding abilities then their reading comprehension of written English might also improve. Such a conclusion is in line with Share's (1995) concept that underpinning phonological coding ability are phonological abilities. However, in the present study there were proficient readers with good phonological skills that also reported using sign-based strategies, suggesting that sign-based coding strategies might also play a role in reading proficiency. Indeed, Miller (1997, 2006) has argued that the use of fingerspelling increases an awareness of some segments in words, and thus enhances the processing of orthography.

Even though there is a substantial theoretical basis detailing how sign language and fingerspelling can be used for coding printed words (Chamberlin & Mayberry 2000, Ewoldt 1996, Fischer 1995, Haptonstall-Nykaza & Schick 2007, Herrera-Fernandez, Puente-Ferreras & Alvardo-Izquierdo 2014, Johnston 2002, Mayberry & Waters 1987, Wauters, Knoors, Vervloed & Aarnoutse 2001) such strategies have limitations. It would seem that while fingerspelling increases an awareness of word segments it does not assist phonemic awareness. Miller (2006) has suggested this is because fingerspelling has the ability to reference letters but not phonemes. Lichtenstein (1998) noted that while many of the participants in his study were switching from one code to another very few participants who predominantly used sign-based coding had a reading comprehension score above the ninth grade level. Similarly, in the present study only the poorest reader from the less proficient group reported an exclusive use of sign-based word coding, suggesting it was ineffective for the processing of written English for that particular participant. In contrast, 10 of the 15 proficient deaf readers reported an exclusive use of speech based-coding. The remainder reported a predominantly speech-based coding strategy. Of the proficient group, 73% read above the ninth grade level.

While it is not possible to conclude from the results in the present study that sign-based coding played a supportive role in the word coding of the participants, the teaching of cheremes (hand-shapes) and graphemes may have the ability to assume a similar role for some profoundly deaf readers, as do phonemes and graphemes for the reader with intact hearing (Herrera-Fernandez et al. 2014). However, it is not clear how this could be incorporated into an instructional program for profoundly deaf adults. Indeed, there is a widespread absence of clear guidelines on how to instruct those with profound deafness to effectively and efficiently code words in print using sign-based coding or fingerspelling (Schirmer & Williams 2003).

CONCLUSION

It is possible that within the time period of testing not all of the participants' coding strategies were captured. In addition, for those who used multiple strategies it was difficult to determine exactly what proportion was devoted to sign-based *vs.* speech based strategies. Additionally, when the participants were given an instructive example (*circle vs. sock*) in the phonemic awareness task some degree of priming may have occurred. Another possible confound is that the participants in the study spanned three generations and as a result probably experienced different forms of reading instruction which may have impacted on their phoneme awareness and subsequent reading scores. It may also be that the age at which the participants had access to visual language might explain differences in reading proficiency rather than phonological processing deficits (Clark et al. 2016). Indeed, as it is likely that most of the participants would have learned sign language as a second language, if at all, spoken language was probably maintained as their primary conduit for thinking, an outcome in line with the 'primary language hypothesis' (Shand 1982, Miller 2007). Padden and Hanson (2000) have also suggested that learning fingerspelling later in life limits the advantages of using such a skill as an internal code for processing words in print.

In summary, findings from this study corroborate previous findings that phonological skills are associated with the processing of written English to some degree. Moreover, they show such gains to be linked to other factors that significantly determined the participants reading skills, such as recoding. While the findings did not provide clear guidelines for instruction two future avenues of investigation are apparent. First, to revisit the proficient readers with both good phonological skills and who reported using sign-based coding, and identify how they were using sign-based coding to connect with written words. Second, if the same groups' sign-based coding appeared to be in a functional relationship with reading comprehension skill then the design and testing of an instructional program to teach profoundly deaf adults how to effectively use sign-based coding during reading should follow. The difficulty of the second task is not underestimated. However, these challenges should not be accepted as an impenetrable barrier to further research, as it is vital to address the disadvantage faced by Australian adults with profound pre-lingual deafness when they read and attempt to comprehend written English.

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APPENDIX 1

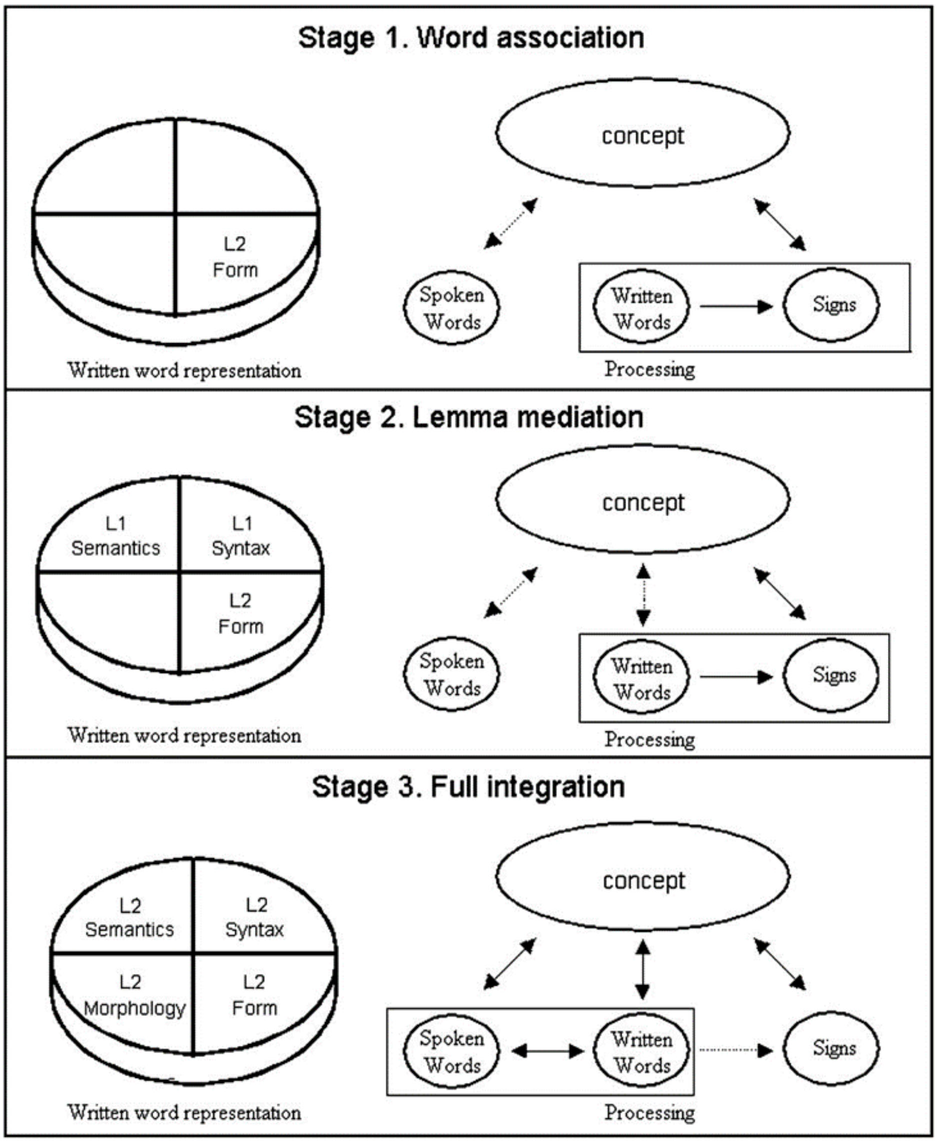

FIGURE 1. A model of lexical development for deaf children (Hermans, Knoors, Ormel & Verhoeven 2008)

APPENDIX 2

Phoneme word sets

	cue	*choice*	*distractor*
Phoneme		*Clustered onsets*	
Same spelling			
p(k)	plate	pig	cat
g(k)	glass	gate	cage
s(f)	spoon	sun	fan
Different spelling			
k(g)	queen	cat	gun
g(k)	green	ghost	key
k(g)	climb	kettle	goat
		Singleton onsets	
Same spelling			
h(f)	hat	horse	fox
l(r)	ladder	light	ring
m(n)	monkey	man	nail
Different spelling			
n(m)	knee	night	milk
k(t)	comb	key	tie
s(f)	circus	salt	fox