Orthographic facilitation of vocabulary learning in children with hearing loss

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This thesis is submitted in fulfilment of the requirements for the Master of Research degree November 2017

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Thesis summary

Oral vocabulary acquisition involves the formation of a link between the phonology and semantics of a newly encountered word. There exists a large body of literature that describes the processes involved in vocabulary acquisition and the factors that influence acquisition in children with typical and atypical development (e.g., Chapman, 2000; de Jong, Seveke, & Veen, 2002; Dillon, 2011; He & Arunacham, 2017; Hollich et al., 2000; Kucker, McMurray, & Samuelson, 2015; Nazzi & Bertoncini, 2003; Waxman & Lidz, 2007; Yu & Ballard, 2007). It is widely acknowledged that vocabulary is crucial for the development of language, communication, reading, and literacy (Biemiller, 2009; Lee, 2011; Ouellette, 2006). Therefore, it follows that if children are not able to acquire vocabulary appropriately, it would impact their overall development and academic success. Vocabulary acquisition is a challenge for children with hearing loss, including those who use appropriate hearing devices such as hearing aids and cochlear implants (Sarchet, Marschark, Borgna, Convertino, Sapere, & Dirmyer, 2014). Surprisingly, there is very little research that directly examines the instruction techniques of factors that can support vocabulary learning in children with hearing loss (Luckner & Cooke, 2010).

One factor that is being increasingly researched as a mechanism to support oral vocabulary learning is orthography. There exists evidence for the orthographic facilitation of vocabulary learning in children with typical development (e.g., Ricketts, Bishop, & Nation, 2009), and in special populations (Lucas & Norbury, 2014; Mengoni, Nash, & Hulme, 2013; Ricketts, Dockrell, Patel, Charman & Lindsay, 2015). This thesis aimed to review the literature on vocabulary acquisition in children with hearing loss and to examine whether they may benefit from the presence of orthography during oral word learning. This thesis is organised in a 'thesis by publication' format, with two parts, that each represent a journal article.

Part One: *Vocabulary acquisition, orthographic facilitation, and its implications for children with hearing loss: A Literature Review.* This section reviews literature vocabulary acquisition in children with typical hearing and children with hearing loss, the rationale and existing evidence for orthographic facilitation in different groups of children.

Part Two: *Orthographic facilitation of vocabulary learning in children with hearing loss.* This section presents an empirical study to examine the possible facilitatory role of orthography for acquisition of novel picture-word mappings in school-aged children with hearing loss who use spoken language as their main mode of communication. The outcomes of the study are discussed in light of the available literature and possible directions for future research in this area are suggested.

Statement of Originality

I, Andrea Ophelia Salins, certify that the work in this thesis titled " Orthographic facilitation of vocabulary learning in children with hearing loss" has not been submitted for a degree, nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

I also certify that this thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and in the preparation of the thesis has been properly acknowledged. All the information sources and literature used for the purpose of this research are indicated in the thesis.

The research presented in this thesis was approved by Macquarie University Ethics Review Committee, reference number: on 27th April 2017.

Signed:

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November, 2017

Acknowledgements

First, I would like to extend a big thank you to each of my supervisors, Distinguished Professor Anne Castles, Professor Linda Cupples and Professor Greg Leigh. I am grateful for the opportunity to work with, and learn from you. Thank you for your kind support, encouragement and expert assistance throughout all the phases of my Master of Research degree.

I would also like to thank Lesley McKnight and Professor Amanda Barnier for all the administrative support. You made all the administrative procedures seem so easy to naviagte through!

I am hugely grateful to the RIDBC, Renwick Centre for allowing me to conduct this study at their institution and the Principal and teachers of the participating school for their support and enthusiasm during towards the research. Heartfelt thanks to all the students and parents for participating in this study.

To my friends and fellow Master of Research fellows, and also others within the Cognitive Science Department thanks for all the support and heartening chats.

And, finally to my family: My grandfather, parents and Jennings. Thank you for always believing in me and encouraging me during the past year and always.

Chapter 1

Vocabulary acquisition, orthographic facilitation, and its implications for children with hearing loss: A Literature Review

Introduction

The majority of children acquire new words quickly and efficiently in their early childhood (Nagy & Scott, 2014). Given that they receive little, if any, direct instruction, the ease with which typically developing children learn new spoken words has intrigued many researchers. The important role of vocabulary in learning to read (Ouelltte, 2006; Ouellette & Beers, 2010) also warrants further study of the process by which children learn new spoken words and their meanings, and possible factors that might facilitate it (Dickinson, 1920; Seashore, 1948; Hoff & Naigles, 2002; Ouellette, 2006; Ouellette & Beers, 2010; Ricketts, Nation, & Bishop, 2009; Nagy & Scott, 2014; Xu & Tenenbaum, 2007; Yu & Ballard, 2007; Yu, 2008).

In contrast to children who have typical development, children with hearing loss find the task of acquiring new spoken words challenging (Hayes, Geers, Treiman, & Moog, 2009; Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2000). Several researchers have found that children with hearing loss lag behind their hearing peers in vocabulary size and rate of vocabulary development (e.g., Dobie & Hemel, 2004; Fagan & Pisoni, 2010). Further, it has been reported that beginning reading ability in children with hearing loss correlates with their vocabulary skills (Kyle & Harris, 2011). It is therefore important to find effective methods for supporting vocabulary acquisition in these children.

Several studies of children with typical development have found that orthographic support—the simultaneous provision of written words when exposing children to new oral vocabulary—improves memory for pronunciations and spellings of those words (Chambre, Ehri & Ness, 2017; Jubenville, 2012; Mengoni, Nash, & Hulme, 2013; Rosenthal & Ehri, 2008; Ricketts et al., 2009; Ricketts, Dockrell, Patel, Charman & Lindsay, 2015; Lucas & Norbury, 2014). The benefit of orthographic support has also been observed in several groups of children who have language-learning difficulties, including children with Down syndrome, Autism

Spectrum Disorders and Specific Language Impairments (e.g., Ricketts et al., 2009; Mengoni et al., 2013), but no studies to date have examined this phenomenon in children with hearing loss. An important question therefore is whether such children would also benefit from orthographic support for vocabulary learning.

In this review, vocabulary acquisition in children with typical hearing and hearing loss, and the way in which it may be supported by orthography, will be examined. Specifically, the following issues will be addressed:

- The mechanisms of vocabulary acquisition and the factors that are known to influence vocabulary acquisition.
- The theoretical bases underlying the concept of orthographic facilitation of spoken word learning and the methods and outcomes of previous research in this field.
- Vocabulary acquisition in children with hearing loss.
- The potential for orthographic support for vocabulary acquisition in children with hearing loss.

1. Processes of Vocabulary Acquisition in Children

A large body of research across different disciplines has addressed the issue of vocabulary acquisition in young children, documenting how children begin to acquire, in a rapid manner, the spoken words to which they are exposed in their early years (Barrett, 1986; Ellis, 1997; Woodward & Maarkman, 1998). A vocabulary burst is said to occur at around two years of age, when development is rapid and the child's repertoire expands significantly (Bloom, 1976). However, this is just the beginning. When children begin school, they are expected to learn many new words, relating to each taught subject. Vocabulary becomes crucial to reading success, and, because reading is a means of acquiring new information, to scholastic success.

Central to vocabulary acquisition is the storage of words' pronunciations and meanings in a mental lexicon for consequent retrieval and usage. The earliest modality through which children acquire new words is through exposure to spoken language. This process requires the child to learn the pronunciation of a word based on its phonology (He & Arunachalam, 2017). This new phonology must then be linked to the concept or meaning (semantics) of the word and stored in memory. For example, to acquire the word 'apple' the child must learn the pronunciation /ˈæpəl/, and that it refers to an edible fruit. Thus, the acquisition of a word entails consolidation of a link between phonology and semantics in the mental lexicon.

1.1. *Theories of vocabulary acquisition.*

Several theories have been advanced to explain the process of vocabulary acquisition, based on different cognitive, behaviourist, social, and interactionist perspectives (for reviews see Chapman, 2000; He & Arunacham, 2017; Hollich et al., 2000; Kucker, McMurray, & Samuelson, 2015; Nazzi & Bertoncini, 2003; Waxman & Lidz, 2007; Yu & Ballard, 2007). Additionally, the nature of vocabulary acquisition and the factors influencing it may differ based on the age of the child. Infants, for example extract the structure of the words in the environment, i.e., infants are sensitive to regularities in the language such as frequency of phoneme order within a word, phonotactic patterns, stress and prosody. This is known as statistical learning, and is believed to assist infants in language acquisition (Jusczyk & Aslin, 1995, Tincoff & Jusczyk, 1999; Saffran, 2003; Romberg & Saffran, 2010). One extensively researched cognitive mechanism that is known to support word learning is termed *fast mapping* (Booth & Waxman, 2003). According to Carey and Bartlett (1978), fast mapping involves the formation of a new lexical entry through brief exposure to a word and its referent. Although seen in children as young as 13 months, fast mapping is most characteristic in the second year of life when the burst in vocabulary development takes place (Alishahi, Fazly, & Stevenson, 2008). Following this period of fast mapping, a secondary cognitive mechanism has been

proposed. This mechanism is term *extended mapping* and requires a greater number of exposures, results in deeper comprehension, and facilitates functional use of the newly acquired vocabulary (McLaughlin, 2006). After sufficient exposure to the new word, it is established in memory and is available for future use.

Aitchison (1987) suggests a different mechanism of vocabulary acquisition that involves three tasks: labelling, packing, and network building. First, the child must assign a label to a novel object or situation. Labelling is said to emerge before 2 years of age. Young children may use various strategies to help them form labels for new objects, such as the principle of mutual exclusivity, which is the assumption that each object has a unique name (Hansen & Markman, 2009; Merriman & Bowman, 1989). The role of theory of mind has also been implicated for identification of speaker intent and referent in order to learn labels of new objects in the environment (Bloom & Markson, 1998). Aitchison suggests that once the label has been acquired, children experiment with the use of this new label, and with time learn the limits to which each word can be generalised to objects within the semantic category. The task of identifying the range of situations where the label or new word can be used is referred to as packaging. Finally, through the process of network building the child learns the relations between the words in their lexicon.

He and Arunachalam (2017) reviewed the various mechanisms that have been suggested to support word learning in children. They suggest that the first challenge in vocabulary acquisition is 'finding the word'. Although the incoming speech is variable, there exist certain regularities in each language, which assist a child to identify word boundaries and find the word. Next, the child must identify the concept to which the word refers. In line with Carey and Bartlett (1978), the authors suggest that a meaning representation is formed even after minimal exposure, through fast mapping. They also emphasise the role of multiple

exposures to the word to allow for extended mapping, which enables generalization to other items within the semantic category.

Older children have multiple opportunities to acquire new words. Oral language input for school-aged children not only inlcudes conversational input, but listening to stories and sometimes direct instruction for word learning. Additionally, literate children also learn words incidentally through their reading (Krashen 1989; Nagy, Herman, & Anderson, 1985).

Finally, numerous computational models have also been developed to account for vocabulary acquisition in children, including modelling the period of the vocabulary burst, the acquisition of different word categories, and the number of exposures required during the process of word learning (Fazly, Alishahi, & Stevenson, 2010; Li, Zhao, & Whinney, 2007; Plunkett, Sinha, Moller, Strandsby, 1992; Reiger et al., 2001; Reiger, 2005; Siskind, 1996; Yu et al., 2005).

1.2. *Factors influencing vocabulary acquisition***.**

In order to learn a spoken word, a child has to extract the word's phonology, learn the pronunciation, and then link it to the concept in the mental lexicon. Given the complexity of this vocabulary acquisition process, it seems inevitable that word learners may combine different mechanisms, and use multiple strategies to complete the task successfully. A number of environmental, perceptual, cognitive, linguistic, and social factors have been proposed to influence vocabulary acquisition (see He & Arunanchalam, 2017; Hollich et al., 2000; Hollich et al., 2000).

A very important and well-researched factor is the environmental input that the child receives. Studies have suggested that children require multiple exposures to consolidate a new word in the mental lexicon (Horst & Samuelson, 2008; McMurray, Horst, & Samuelson, 2012; Mather & Plunkett, 2009). Although children learn incidentally during their early years, direct vocabulary instruction is invaluable to vocabulary acquisition as children get older and word

learning becomes more bound to literate and academic contexts (Biemiller, 2006; McKeown, Beck, & Sandora, 2012). To make use of these environmental cues adequately, children need to have a social understanding (Baldwin, Markman, Bill, Desjardins, Irwin, & Tidball, 1996; Baldwin & Moses, 2001; Ferguson & Waxman, 2016). They need to understand the social intent of the speaker for correct identification of the referent and formation of word-referent links (Bloom & Markson, 2001).

Linguistic factors including phonology, semantics, morphology, and syntax are also key factors in word learning. Phonological sensitivity, the ability to encode, discriminate, or retrieve phonological representations, is a strong predictor of vocabulary learning in children (de Jong, Seveke, & Veen, 2002; Dillon, 2011). Phonological short-term memory, a part of the working memory system, is thought to be particularly vital for this process (Baddeley, Gathercole, & Papagno, 1998; Gathercole, Hitch, Service, & Martin 1997; Gupta & Tisdale, 2009; Kim, 2015, 2017; Morra, & Camba, 2009). Morphological awareness is also reported to influence vocabulary acquisition in school-aged children, as the words they encounter become more complex (Dockrell & Messer, 2004; McBride-Chang, Wagner, Muse, & Shu, 2005). Apart from these factors, word-properties such as word class (nouns are acquired more easily than verbs or adjectives), length of the word (shorter words are easier to acquire than longer ones), morphological complexity, semantic complexity (Dockrell & Messer, 2004), and spelling-sound regularity also influence acquisition of new words. Two other properties of words, namely, phonotactic probability and neighbourhood density also determine the ease of acquisition of new words. Neighbourhood density refers to the number of words in the lexicon that are phonologically similar to the given word which can be obtained by replacing or deleting one phoneme at a time (Luce & Pisoni, 1998). Storkel & Lee (2011) found that while preschool children learned words with sparse neighbourhood density more quickly, there was a definite advantage of dense neighbourhood density for word retrieval. Phonotactic probablity is the

term used to describe the likelihood of occurrence of a sound sequence in words of the language. Studies suggest that words with low probability sound sequences are more easily recognised, and therefore learned more efficiently than words with high phontactic probability (Heisler & Goffman, 2016; Firsch, Large, & Pisoni, 2000; Storkel & Adolf, 2009; Storkel & Lee, 2011). However, studies suggest that children with hearing loss who use cochlear implants do not benefit from such effects of phonotactic probability and neighbourhood density (Han, Storkel, Lee, & Yoshinaga-Itano, 2015).

Among perceptual abilities, the most obviously important skill is auditory perception which can directly impact spoken word acquisition. Literature suggests that early auditory ability, such as sensitivity to transitional cues, word boundaries, and phonetic distributional patterns impacts later language development in children with typical hearing (Benasich & Tallal, 2002; Fernald, Perfors, & Marchman, 2006; Trehub & Henderson, 1996; Marchman & Fernald, 2008; Mueller, Frederici, & Mannel, 2012). It is with the help of these auditory perceptual abilities that infants as young as 7- to 8- months of age are able to segment words from the continuous speech stream (Jusczyk & Aslin, 1995), which they can link to meaning and acquire new words by the time they are a year old (Werker & Young, 2005; Singh, Reznick, & Xuehua, 2012). Children who have impaired auditory perception, such as children with hearing loss face challenges in vocabulary acquisition.

Several broader cognitive factors have been identified as important for vocabulary acquisition. Attentional control is essential for children to be able to identify and benefit from relevant word learning opportunities (Akhtar & Gernsbacher, 2007; Reiger, 2005; Sanders, Stevens, Coch, & Neville, 2006). Statistical learning ability helps children to predict regularities in their language, identify word boundaries in the speech stream, and thereby acquire new words (Saffran, 2001, 2002, 2003; Swingley, 2005). Another cognitive skill—associative learning ability—is thought to be important for learning word-referent links and to

attribute meaning to the string of sounds that form a word (McMurray et al., 2012). Finally, inferencing skills support the children during incidental word learning (Kuhn & Stahl, 1998).

1.3. *Summary*.

The process of vocabulary acquisition has received extensive attention in the literature. Developmental scientists have identified various mechanisms that children may employ for vocabulary acquisition. Young children make use of fast mapping for quick, incidental vocabulary learning. However, multiple exposures are required for consolidation of the word in the mental lexicon. As children grow older, they are provided with more opportunities for word learning through oral input, written input and direct instruction. Overall, children seem to use an interactionist approach by making use of various linguistic, cognitive, and social abilities to succeed at word learning.

2. Learning Spoken Words in the Presence of Orthography

Once children learn to read, the skills that can be used to support vocabulary acquisition change markedly (Cain & Oakhill, 2011; Duff, Tomblin, & Catts, 2015; Stanovich, 1986). In English, children are exposed to the printed alphabet and learn that the letters of the alphabet are a code for the language's most basic sounds, or phonemes. For children with this basic orthographic knowledge, the presence of the written form while learning new words introduces a new entity into the word-learning equation, as depicted in Fig 1. Children are able to use their alphabetic knowledge to form a link between the spelling (orthography) and the pronunciation (phonology) of the word, which facilitates its retention in memory (Ehri, 2014). Recently, researchers have further suggested that the presence of an orthography-phonology link may also strengthen the phonology-semantics link in the mental lexicon and result in better word learning and retention; that is, that oral vocabulary learning is supported by the presence of orthography (Ricketts et al., 2009; Rosenthal & Ehri, 2008; Jubenville, 2012; Mengoni, et al.,

2013). The concept of orthographic facilitation of spoken word learning derives support from the theoretical frameworks described below.

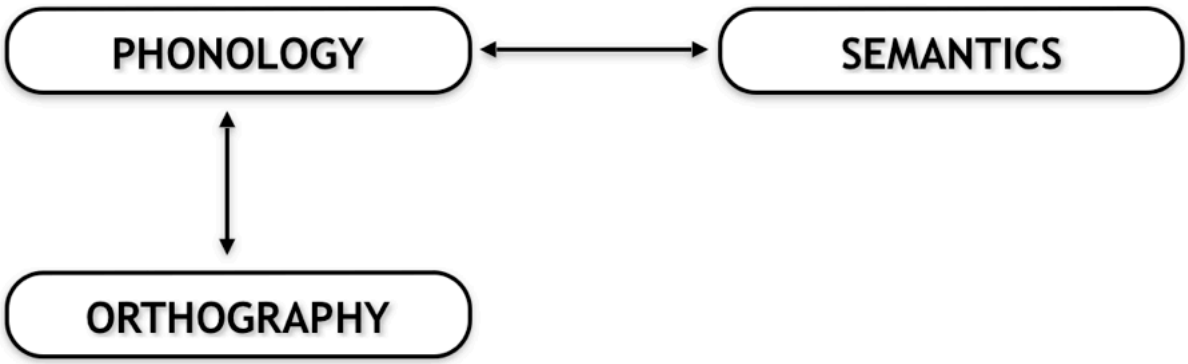

Figure.1 - Addition of orthography while learning the phonology - semantics link

2.1 *Theories of orthographic facilitation*.

One key theory that supports the concept of orthographic facilitation is the *word identity amalgamation theory* (Ehri, 1978, 2014). This theory proposes that every word has a number of identities, namely, pronunciation (phonology), meaning (semantics) and grammar (syntax). When a child begins to read and becomes capable of identifying printed words, another identity—orthography—is added to form a single unit consisting of several identities of the same word. This 'amalgamated' identity is hypothesised to provide an easier mechanism for word recognition than a single identity such as meaning alone. Although this theory was initially described in relation to printed word recognition, the benefits of a more efficient amalgamated identity for oral vocabulary learning and retrieval has been suggested (Rosenthal & Ehri, 2008). Rosenthal et al. (2008) suggested that orthography, being more reliable than the transient phonological information, helps to secure the pronunciation of a new word within an amalgamated identity. Additionally, introducing orthography provides information of the word in two modalities, auditory (pronunciation) and visual (spelling). Doing so may improve memory for the words by virtue of the dual coding theory (Sadoski & Paivio, 2004). The second

theory that is often used as the basis for a proposed facilitatory effect of orthography for word learning is the *lexical quality hypothesis* (Perfetti & Hart, 2001). Similar to the word identity amalgamation theory, the lexical quality hypothesis also places emphasis on the availability of more word-specific information. According to Perfetti (2007), the 'lexical quality' of a word depends on the extent to which the word's orthography, phonological, syntactic, semantic and pragmatic information is available in the mental lexicon. It is argued that greater word knowledge results in better quality of representation and hence the word is more 'available' for recall. It follows that a word learned in the presence of orthography will be of higher lexical quality than one without, and so will be identified more easily and pronunciations and spellings retrieved more accurately.

In sum, these two theories suggest that having more detailed information of a word results in better learning, retention, and retrieval of the pronunciation, meaning, and spelling of the word.

2.2. Evidence for orthographic facilitation

In the first research exploring the notion of orthographic facilitation, Ehri and Wilce (1979) conducted a series of experiments in children from Grade 1 (mean age: 6.43 years) and Grade 2 (mean age: 7.78 years). Using paired-associate learning tasks, they assessed whether presence of spellings made it easier to learn and recall consonant-vowel-consonant (CVC) sound sequences that were taught as the names of geometric figures. The results were positive and the authors concluded that orthography has 'mnemonic' value for phonological learning in beginning readers.

Rosenthal and Ehri (2008) further examined this mnemonic value of orthography for learning the pronunciations of new words, by investigating whether the formation of links between orthography and phonology strengthened connections with semantics. In two experiments, they taught second graders (mean age 7.7 years) and fifth graders (mean age 10.11

years) the pronunciations and meanings of a list of concrete nouns. The words were taught with drawings of the referents. Each word was given a definition and was embedded in sentences for further clarification of meaning. Children learnt the pronunciations and definitions in spelling-present and spelling-absent conditions. Word learning was tested after a delay of one day, using slightly different tasks for the two groups. The younger children were given three tasks (i.e., word recall in response to a definition, spelling to dictation, and matching words to sentences) to assess their learning of pronunciation, spelling, and meaning respectively. The older group was given four different tasks (i.e., oral cloze task, picture naming, recalling definitions on listening to the target word, and matching words to new pictures) as well as spelling to dictation. Rosenthal and Ehri found a clear advantage of orthography for learning meaning, pronunciation and spelling in both groups of children. They explained the advantage of learning in the presence of spelling using the word amalgamation theory. Specifically, they suggested that orthography provided a reliable means of clarifying the transient phonemic constituents of the word. Another proposed explanation was that the dual coding—visual and auditory—enhanced memory for the word. They also reported that better readers, who were equipped with superior orthographic knowledge, benefited more from the presence of spellings.

Ricketts et al. (2009) constructed 12 nonwords of varying spelling-sound consistency: consistent (e.g., joig - /jɔɪg/), inconsistent consonant (e.g., knarb - /nɑb/), and inconsistent vowel (e.g: dowf - /daʊf/). These nonwords were paired with novel pictures and taught to children as “objects that an alien might use”. Children were first familiarised with the pronunciations of the novel words and then the learning phase was initiated. The words were taught in three repetition and three production trials. During the repetition trials, the task was to look at the picture, listen to the word and repeat it. Mispronunciations were corrected. In the production trials, the task was to name the picture displayed. Half the stimuli were presented

with the written word accompanying the picture (orthography present condition) and half with the orthography absent; however, no attention was drawn to the presence of the orthography. Testing was conducted during the same session and included two tasks; nonword-picture matching, and spelling to dictation. Learning was also assessed during training by monitoring accuracy on the three production trials.

Ricketts et al. (2009) found that learning increased over sessions, and that the presence of orthography facilitated learning of the phonology-semantics link. They did not analyse accuracy on the nonword-picture-matching task because the children's performance was at ceiling. However, they found that reaction times were reduced for items learnt in the presence of orthography, pointing towards a facilitatory effect for all of the target nonwords. For the spelling test, orthographic facilitation was found for the nonwords with inconsistent spellings, but not for consistent ones. Error analysis of spellings revealed that children had not acquired word-specific spellings during the brief exposure to orthography and were spelling by translating from phonology to orthography. In summary, the study demonstrated orthographic facilitation of vocabulary learning in 8- to 9-year-old typically developing children. Based on the lexical quality hypothesis, the authors concluded that teaching children new spoken words in the presence of orthography enriched the input (i.e., both phonology and orthography) provided. The authors further noted that this effect was brought about by a brief and incidental exposure to spellings, indicating that children automatically used the orthography-phonology link, which then further strengthened the link between phonology and semantics.

Jubenville (2012) adapted the paired-associate word learning paradigm and extended these findings to another opaque language, French. The same pictures used by Ricketts et al. (2009) were used. A group of 79 children in Grade 3, matched for their reading and decoding abilities, were divided into 3 groups: one learning nonwords without orthography, and two learning nonwords with orthography under consistent or inconsistent spelling conditions. The

outcome measures used were the number of trials required to learn the pronunciations of the nonwords, picture naming, nonword-picture matching, and spelling. The results indicated that children learned the pronunciations of the words faster in the orthography-present condition, further adding to the evidence for orthographic facilitation of word learning. Benefits were also evident in the picture naming, nonword-picture matching, and spelling tasks. In order to examine whether these benefits extended beyond the learning period, three post-tests were conducted one day after testing: recalling the label (expressive vocabulary), spoken-label to picture matching (receptive vocabulary) and spelling to dictation. The benefit of orthography persisted for receptive vocabulary and spelling. However, in contrast to previous literature, orthography did not have a significant effect on the recall of pronunciations during posttest. Jubenville (2012) attributed this result to the between-subject design and to the general difficulty of the pronunciation-recall task. A recent study by Chambre et al. (2017) demonstrated a similar advantage of orthography in slightly younger 6- and 7-year-old children. In that study, the benefits persisted two weeks after the learning phase, but were found only for learning pronunciations and not meanings. The reason suggested for this finding was that, being younger, these children would not have a grapho-semantic system capable of using orthography to learn meanings.

2.3. *Orthographic facilitation in special populations*

Following these studies with typically-developing children, several researchers have attempted to extend the findings to different populations. Mengoni et al. (2013), examined whether children with Down Syndrome would benefit similarly from the presence of orthography. They studied orthographic facilitation for learning spoken words in 17 children with Down Syndrome aged 7 to 16 years, and compared it to the effect in reading level matched typically-developing children aged 5 to 7 years. Keeping in mind the speech production difficulties characteristic of Down Syndrome, 10 nonwords consisting only of phonemes

acquired by 4 years of age were chosen as stimuli. These were paired with unfamiliar pictures. Vocabulary learning was conducted in two conditions; orthography present, where the spelling of the nonword was provided, and orthography absent, where a string of three randomly selected Greek letters was presented. Deviating from previous studies, a sentence cue, "This is how we spell it" was provided for the presence of orthography and "This is how aliens spell it" for Greek symbols in the orthography absent condition. The experiment consisted of a series of three trials: (a) repetition and phonological consolidation (b) picture-word matching, and (c) picture naming, with each trial repeated four times. Children heard the word again as feedback along with the spelling. The outcome measures were performance on the production trials during learning, and performance on a post-training picture-naming task. Results revealed a similar level of spoken word learning as well as degree of orthographic facilitation for both groups of children on both outcome measures. Mengoni et al. expected a greater degree of facilitation for the children with Down Syndrome given their strong visual short-term memory and weak verbal short-term memory; however, the results did not suggest any such between-group differences in learning. The authors concluded that having a control group matched for decoding ability, rather than single word reading, might prove to be advantageous in exploring the relative degree of orthographic facilitation in this population.

In a study comparing orthographic facilitation between children with autism spectrum disorders (ASD, n = 20) and typically developing children (n=21), Lucas and Norbury (2014) taught 16 low frequency secondary school level science words to 7- to 12-year-old children. Similar to previous studies, during the learning phase, children learned stimuli in the two conditions (orthography present and orthography absent). Deviating from previous studies, the stimuli were presented only twice because more exposures resulted in ceiling effects on the post-tests for typically developing children. A semantic component was also included by categorising the stimuli into 'plant-related,' 'animal-related' or 'neither' categories. Picture

naming, spoken-word-to-picture matching, and an orthographic choice task were used to test phonological, semantic, and orthographic learning respectively. On testing immediately after learning, both groups benefited from the presence of orthography on all measures, with a greater degree of facilitation observed for the ASD group. The ASD group demonstrated better phonological learning while the typically developing group learned the orthography better. The advantage of orthography present over the orthography absent condition was retained 24 hours after learning. A particular strength of this study was the use of eye tracking to monitor attention given to the orthography during the learning phase. These data revealed that children with ASD actively searched for the additional support in the orthography absent condition, indicating that the spelling might indeed have supported learning.

Ricketts et al. (2015) studied orthographic facilitation in three groups of children; those with specific language impairment (SLI), ASD, and typical development. The children where between 8- and 13-years-of-age and were matched in triplets for age and nonverbal reasoning. The SLI and ASD groups did not differ significantly on word or nonword reading but had significantly lower word reading than the typically developing group. The learning paradigm followed was identical to Ricketts et al. (2009). All three groups showed benefits of orthography for learning oral vocabulary, thereby extending findings to children with SLI as well.

2.4 *Summary.*

To summarise, there is extensive literature on the mechanisms involved in, and factors influencing, vocabulary acquisition in children. The role of orthography as an important linguistic factor for oral word learning is increasingly being researched. Furthermore, the benefits of orthography for spoken word learning are observed not only for children with typical development but also children from special populations who are known to display weaknesses in oral language, reading skills, and language learning in general. To date,

however, there have been no studies of orthographic support for word learning in children with hearing loss.

3. Oral vocabulary learning in children with hearing loss

Language development in children with hearing loss shows large variability, owing in part to the variability in the nature and level of hearing impairment in this population. For the purpose of this review, the focus will be on vocabulary acquisition in children with hearing loss who communicate orally and use hearing devices (i.e., hearing aids or cochlear implants).

3.1 *Vocabulary deficits in children with hearing loss.*

Children with hearing loss face various challenges in learning new words. In comparison to hearing children, they often have access to fewer incidental learning opportunities and miss word-learning opportunities because of the diminished quantity and quality of auditory input that they receive. Hermans, Wauters, Willemsen, & Knoors (2015) reviewed the research on vocabulary acquisition in children with hearing loss. They emphasised that research has found repeatedly that children with hearing loss using hearing aids or cochlear implants tend to have smaller spoken vocabularies and poorer vocabulary learning than hearing children.

As described in earlier sections, there are numerous theories of the vocabulary acquisition process in children with typical hearing. It is known that children with hearing loss face difficulties in word learning. However, fewer studies have focused on the mechanisms of vocabulary acquisition in this population. Some researchers have examined fast mapping in children with hearing loss (Pittman, Lewis, Hoover, & Stelmachowicz, 2005; Stelmachowicz, Pittman, Hoover, & Lewis, 2004). The outcomes of these studies suggest that children with hearing loss need a greater number of exposures to learn a new word when compared to their hearing peers. Children with hearing loss using hearing aids or cochlear implants seem to be able to learn words using fast mapping, which is influenced by age at identification and

aiding/implantation (Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Schorr, Roth, & Fox, 2008), existing vocabulary skills (Pittman et al., 2005), and phonological working memory (Willstedt-Svensson, Lofqvist, Almqvist, & Sahlen 2004).

A question of particular importance is whether these children are able to learn new words and retain them in memory over the longer term. Houston, Carter, Pisoni, Kirk, and Ying (2005) examined word learning and retention in 2- to 5-year old children using cochlear implants. This group of children was found to be much slower than hearing children in learning word-referent pairs. Additionally, word recall was also poor, after only a 2-hour delay. In another study, Walker & McGregor (2013) found that although preschool children using cochlear implants performed more poorly than age-matched peers on word learning, their performance was on par with hearing children matched for vocabulary skills. However, they showed poor retention (tested after 1 day), and were unable to extend the newly learned words to similar objects.

Therefore, there exists some evidence for the use of fast mapping in children with hearing loss who use cochlear implants (e.g., Walker & McGregor, 2013). However, it is evident that word learning is a difficult task in this population and that their memory for meanings and pronunciations of words is generally poorer than for children without a hearing loss.

3.2 *Factors responsible for vocabulary deficits in children with hearing loss.*

A major factor that results in poor vocabulary skills among deaf children is the diminished input and fewer opportunities for incidental word learning (Hermans et al., 2016). As previously described in section 1.2, the auditory perceptual abilities are crucial for spoken word acquisition. Children with hearing loss have deficits in this domain, which impacts their word learning ability to a great extent. Children who receive cochlear implants at an early age are at an advantage for word learning when compared to those undergoing late implantation in

terms of overall vocabulary outcomes as well as learning rates (e.g. Hayes et al., 2009; Kirk, Miyamoto, Lento, Ying, O'Neill, & Fears, 2002; Nicholas & Geers, 2006; Willstedt-Svensson et al., 2004).

The vocabulary deficits widely reported in children with hearing loss might partially be the consequence of poor phonological working memory (Gathercole & Baddeley, 1993; Willstendt-Svensson et al., 2004; Houston et al., 2005) and weak phonological representations (Harris & Beech, 1998, James, Rajput, Brinton, & Goswami, 2008). Given that oral vocabulary acquisition requires children to learn the link between phonology and semantics, a child must retain the sound pattern or sequence of a new word in short term memory for long enough to link it to the relevant meaning. If the child fails to retain the phonological form of the word, they will in turn fail to learn its pronunciation and, as a consequence, the phonology-semantics link would not be established. It is also reported that children with hearing loss using cochlear implants fail to take advantage of linguistic cues such as phonotactic probablities, neighbourhood density and word frequency, which are important in the early stage of spoken word learning (Section 1.2).

It is evident from this review of literature that a large proportion of children with hearing loss do not achieve age appropriate vocabulary skills due to perceptual, linguistic and cognitive factors. Hence, there is a great need to identify factors that may facilitate spoken vocabulary acquisition, and thereby improve language and literacy outcomes in this population.

3.3 *Interventions to support vocabulary acquisition in children with hearing loss.*

Luckner and Cooke (2010) completed a review of 41 studies of vocabulary learning in children with hearing loss conducted between 1967 and 2008. The age range of the children studied was from 3 to 21 years. Of these, 10 studies investigated methods or programs to support vocabulary acquisition in children with hearing loss. Overall, the strategies did not prove very effective for teaching vocabulary to children. However, the use of multimodal

scaffolding via a computer-based program was found to be advantageous for the learning of new words (Barker, 2003). Luckner and Cooke emphasised the dearth of research in this area, especially in exploring possible vocabulary instruction methods that may support word learning in children with hearing loss.

Paatsch, Blamey, Sarant, and Bow (2006) have advocated a more direct approach for vocabulary instruction. They developed a program to teach 5- to 12-year-old children 70 words as part of a 15-week curriculum. The words were presented pictorially. The activities in vocabulary training included discussion of the word meanings, using the words in sentences and in discourse to learn the semantic and syntactic use of the word. This direct method of vocabulary training improved the knowledge of word meanings significantly.

There exists some evidence for the effectiveness of a semantic teaching method of intervention for vocabulary acquisition in preschool children using cochlear implants (Lund & Schuele, 2014). Five children were taught 60 words as labels for unknown pictures over a period of ten weeks. They were then provided with detailed semantic descriptions for each word. Receptive and expressive word learning were assessed using a picture-word-matching task and a labelling task respectively. Results revealed an improvement in receptive word learning after semantic teaching. However, the intervention did not show an effect for expressive word learning. It is notable that different sets of words were used in training and testing, indicating that this study examined whether training affected word learning performance in general rather than learning of individual novel words.

3.4 *Summary.*

To sum up, the studies on vocabulary acquisition in children with hearing loss reveal that these children are slower to learn new words and need a greater number of exposures. Furthermore, they show poor retention and extension of new words. These learning difficulties could be the result of inadequate input, limited word learning opportunities, poor language

skills (vocabulary and phonology), and/or limited working memory capacity. There is great scope for further research into the mechanisms of word learning in children with hearing loss.

4. Conclusions and future directions

Vocabulary acquisition is a widely researched area of language development in children. Numerous theories, based on language, cognition, and social-pragmatics have been proposed to explain word learning. Additionally, some hybrid models have also been proposed, acknowledging the use of multiple mechanisms and strategies for vocabulary acquisition (e.g. e.g., Hollich et al., 2000). In typical populations, several factors that support vocabulary development have been identified, including the use of direct instruction.

A more recent line of research has focused on the facilitatory effect of orthography for vocabulary learning. Drawing support from theories such as dual coding theory, word identity amalgamation theory, and the lexical quality hypothesis, researchers have provided evidence for the effective use of orthography to support vocabulary acquisition in children with typical development, SLI, ASD and Down Syndrome. The results are promising, and encourage further research in other populations that face word learning difficulties, such as children with hearing loss.

It is evident from the available literature that vocabulary learning poses a challenge to children with hearing loss. Several studies propose direct instruction strategies and suggest the use of some scaffolding to support vocabulary learning (Hermans et al., 2015). However, little empirical support for the effectiveness of different methods exists. Ricketts et al. (2009) suggested that the orthography could be used as a compensatory strategy for children who have good visual or orthographic skills but face difficulty in learning new spoken words. It would appear possible that orthography could provide the necessary scaffolding, release the load on phonological short-term memory, and facilitate formation of the crucial phonological-semantic link and might result in better word learning in children with hearing loss.

Chapter 2

Orthographic facilitation of vocabulary learning in children with hearing loss

Abstract

Vocabulary is known to play a crucial role in children's reading and literacy acquisition. Therefore, several attempts have been made to identify factors that may support vocabulary learning, such as the presence of orthography while learning new words. Researchers have established that the presence of orthography has a facilitatory effect on learning the pronunciation and meanings of new words in school-aged children (e.g., Ricketts, Nation & Bishop, 2009). The aim of this study was to examine whether the incidental presence of orthography can also facilitate word learning in children with hearing loss. Since children with hearing loss often have weak phonological skills, we hypothesised that orthography would provide scaffolding for the acquisition of novel words and strengthen the phonology-semantics link in the mental lexicon. Fourteen children aged 7 to 12 years were taught novel picture-word pairs using repetition and production tasks. The orthographic forms were presented incidentally for half of the stimuli. Word learning was assessed using pronunciation, picture-word matching, and a spelling test. During training, children named pictures more accurately when their names were learned in the presence of orthographic forms than without them. However, a corresponding benefit of orthography was not found for either accuracy or reaction time in the word-picture matching task. Despite only brief incidental exposure, the children were better able to retrieve the spellings of words learned in the orthography present condition. Overall, the results suggest that children with hearing loss show some benefit from the presence of orthography in learning new spoken words.

Introduction

Acquisition of new oral vocabulary is a complex process that involves learning a word's pronunciation (phonology) and meaning (semantics), and forming a link between the two. Children's oral vocabulary is typically measured in terms of tests of *receptive vocabulary*, which assess children's ability to go from phonology to meaning in comprehension tasks, and *expressive vocabulary* which assess children's ability to go from meaning to phonology in production tasks (Burger & Chong, 2011). In young children, vocabulary acquisition is of utmost importance for development of language, communication, and subsequent reading and literacy skills (e.g., Biemiller, 2009; Ouellette, 2006; Ricketts, Nation, & Bishop, 2009). Therefore, it is unsurprising that children's vocabulary acquisition and factors that facilitate such acquisition have been extensively researched. Here, we explored vocabulary acquisition in children with hearing loss and, specifically, examined whether providing orthographic (written word) support could assist in the learning of new spoken words.

The Process of Vocabulary Acquisition.

Young typically-developing children rapidly and automatically acquire the meanings and pronunciations of words they encounter in their native language, in an apparently incidental fashion. Several theories have been proposed to describe this incidental process of vocabulary acquisition. Carey and Bartlett (1978) suggested that children as young as 13 months can form word-referent links following very few exposures, using a mechanism known as 'fast mapping'. Similarly, Aitchison (1987) posits three tasks that are required for vocabulary acquisition; namely, labelling, packaging and network building. According to this theory, a child first learns to assign labels to objects or events in their environment. After labelling, the child learns to package together all instances in which the word can be correctly used. Finally, the child learns the semantic relations between words in their vocabulary through network

building. In young children, this learning appears to occur with minimal explicit instruction or assistance from parents or teachers.

Apart from incidental vocabulary acquisition (e.g., Carey & Bartlett, 1978; Aitchison, 1987), children also receive explicit vocabulary instruction during the early preschool and school years, aimed at maximising their learning. It has been suggested that explicit vocabulary instruction must start early and provide rich conceptual and contextual information to consolidate the word in the mental lexicon (Beck, McKeown & Kucan, 2002; McKeown, Beck, & Sandora, 2012; Perfetti & Hart, 2002). Many different methods of vocabulary instruction have been proposed, examined and compared in typically developing children at different grade levels (*e.g.,* Biemiller & Boote, 2006; Coyne, McCoach, Loftus, Zipoli, & Kapp, 2007; Marulis & Neuman, 2010). In addition, as children learn to read, a major part of vocabulary is acquired through the process of reading itself (Nagy, Herman, & Anderson, 1985).

Vocabulary acquisition in children with hearing loss.

Hearing loss is known to affect language development in children, including the development of receptive and expressive vocabulary (e.g., Sarchet, Marschark, Borgna, Convertino, Sapere & Dirmyer, 2014). With technological advancements, hearing aids and cochlear implants are able to provide language input to children learning spoken language. Nevertheless, vocabulary acquisition remains a challenge in this group of children (e.g., Geers, 2006; Hermans, Wauters, Willemsen, & Knoors, 2016; Lund & Douglas, 2016; Stelmachowicz, Pittman, Hoover & Lewis, 2004). The word learning task continues to be a challenge during the school years, when children are expected to learn a large number of subject-specific novel words. Many school-aged children with hearing loss learn fewer words than their age-matched peers, and most fail to attain vocabulary skills similar to their peers throughout their school years despite use of adequate amplification such as hearing aids and cochlear implants (e.g. Hayes, Geers, Treiman, & Moog, 2009; Lund, 2016; Sarchet,

Marschark, Borgna, Convertino, Sapere, & Dirmyer, 2014; Walker & McGregor, 2013). For instance, Johnson and Goswami (2010) found that 5-15-year-old children with hearing loss who used hearing aids and cochlear implants had lower receptive and expressive vocabularies than their reading-matched peers with normal hearing.

Although great variability has been reported (e.g. Marschark, Convertino, McEvoy & Mastellar, 2004), it is clear that at a group level, children with hearing loss exhibit poorer vocabulary skills than children with typical hearing. The importance of vocabulary skills for reading and literacy success is well known (Kyle & Harris, 2011). Given that children with hearing loss do not benefit greatly from opportunities for incidental oral word learning (Hermans et al., 2016), and that most fail to attain vocabulary skills similar to their peers throughout their school years (*e.g.,* Geers, 2006; Lund & Douglas, 2016; Sarchet et al.,2014; Stelmachowicz et al., 2004), it is of great importance to identify vocabulary instruction strategies that are effective in this group of word-learners.

A review of studies examining vocabulary learning in children with hearing loss (Luckner & Cooke, 2010) revealed that, among 41 studies conducted between 1967 and 2008, only 10 studies focused on vocabulary intervention. This finding directs attention to the need for further research in this field. Some of the studies provided evidence for the use of technology to teach pronunciations and spellings of words to children with hearing loss (e.g. Barker, 2003; Hermans et al., 2016). The use of linguistic strategies was also suggested, such as semantic, morphological and metalinguistic strategies (Easterbrooks & Beal-Alvarez, 2013; Hermans et al., 2016; Lund & Schuele, 2013). In a recent study, Lund et al. (2016) compared the effectiveness of three methods of vocabulary instruction for preschoolers with hearing loss. The results indicated that children with hearing loss learned vocabulary better when given direct instruction (which encompassed repetition, picture matching and picture naming) than they did through play-based or incidental exposure.

Although there is evidence that children with hearing loss benefit from direct instruction and linguistic support during word learning, further research is warranted to identify factors that can effectively support word learning and memory for pronunciations in children with hearing loss. Similar to hearing children, children with hearing loss must retain the sound pattern of a novel word in phonological short-term memory, and link this new phonological form to the meaning to form a new entry in the mental lexicon. The word learning difficulties in the DHH population could partially arise from their documented weak phonological representations (Nittrouer, Caldwell-Tarr, Low, & Lowenstein, 2017; Pisoni & Cleary, 2003), making it difficult for them to learn the word's pronunciation and subsequently, to acquire the word. The key therefore is to identify strategies that have the potential to overcome these difficulties.

Orthographic Facilitation of Oral Vocabulary Acquisition.

An interesting line of research being pursued in the last decade highlights the provision of spelling or *orthography* as an important factor that can facilitate vocabulary acquisition in young children (Jubenville, 2012; Lucas & Norbury, 2014; Mengoni et al., 2013; Ricketts et al., 2009; Ricketts et al., 2015; Rosenthal & Ehri, 2008). Vocabulary learning, as described earlier, requires a child to learn the link between pronunciation (phonology) and meaning (semantics) of a new word. Once literacy instruction commences, children are able to develop basic orthographic knowledge, which enables them to add additional information to the representations of words in their mental lexicon, namely, spelling.

Two theories have been proposed to explain the benefits of additional orthographic information for word learning: (1) *word amalgamation theory* and (2) the *lexical quality hypothesis*. According to the word amalgamation theory (Ellis, 1978) children learn a number of identities for each word during acquisition, such as their phonological, semantic and syntactic identities. The identities for each word, though acquired over time, become

amalgamated to form a single unit representing that word. The theory suggests that this amalgamated form provides an easier word recognition strategy. For example, if the child sees the word 'apple' which has an amalgamated identity, they could use the orthographic image to retrieve the pronunciation, without having to perform letter-by-letter decoding. In a similar vein, Perfetti and Hart (2001) have proposed the lexical quality hypothesis, which posits that word retrieval becomes more accurate and efficient as the quality of representation improves. The 'lexical quality' of a word's representation is determined by the extent to which phonological, semantic, syntactic and pragmatic information specific to the word are available in the lexicon. Therefore, if orthography were to be provided while learning a new word-referent pair, it would result in a better-quality representation of the word in the mental lexicon, and allow for more accurate and efficient retrieval of the word's pronunciation and spelling (Figure 2).

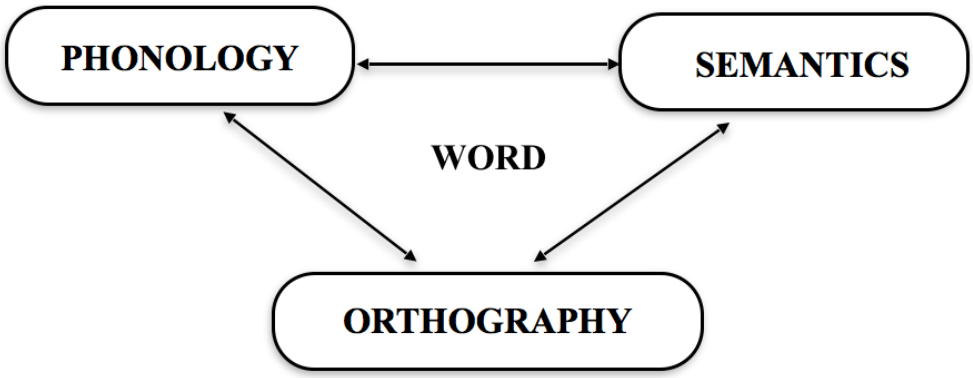

Figure 2. Word representation in the mental lexicon (Based on the lexical quality hypothesis, Perfetti & Hart, 2001)

Based on these theories, several researchers have examined the influence of orthography on word learning in children. Rosenthal and Ehri (2008) taught a group of 2nd and 5th grade children low frequency nouns paired with picture referents and their definitions. Word learning was tested after one day using tasks such as picture naming, definition recall, spelling, and spoken word-to-picture matching. The presence of orthography benefitted the children's

performance on all the post-training tests, leading the researchers to conclude that the presence of orthography served as a mnemonic for learning the pronunciations of new words.

Ricketts et al. (2009) examined whether orthography facilitated novel word learning in 58 school children aged 8 to 9 years. Twelve nonword stimuli were paired with novel pictures and were taught in the presence or absence of orthography. Before the word learning phase, children were familiarised with the pronunciations of the nonword stimuli. During the training phase, the children were required to repeat words and produce the name from pictures, with feedback. Testing was conducted in the same session and included two tasks: nonword-picture matching, and spelling to dictation. In the nonword-picture matching task, children heard the stimulus and matched it to the target from among four distractors. Participants were faster in this task in the orthography present condition than in the orthography absent condition, but there were no differences in accuracy between the two conditions. Spellings of the stimuli were also manipulated to represent different levels of spelling-sound consistency, and the presence of orthography was found to be important only for learning the spellings of inconsistent words. Therefore, Ricketts et al. concluded that children had not learned word specific orthography during the brief, incidental exposure, but were spelling by translating from phonology to orthography.

Following a slightly different, between-subjects design, Jubenville (2012) extended these findings to French speaking children in Grade 3. Similar to Ricketts et al. (2009), benefits of orthography were obtained during learning (as evidenced by improved naming accuracy and faster learning of pronunciations), and in the post-learning nonword-picture matching and spelling tests. However, the benefit for memory of pronunciations did not remain when children were re-assessed the next day.

Orthographic Facilitation in Special Populations.

Orthography has also been found to support spoken vocabulary acquisition in different groups of children who are known to have word learning difficulties. Mengoni et al. (2013), examined the orthographic facilitation effect for word learning in 17 children with Down syndrome aged 7 - 16 years. The children were taught 10 nonwords which consisted only of phonemes acquired by 4 years of age, since children with Down syndrome often display speech production difficulties. Similar to the previous studies, Mengoni et al. conducted a paired-associate word learning task in two conditions: orthography present and absent. However, in this study, the orthography absent condition consisted of a string of three randomly selected Greek letters; and attention was drawn to the presence of the spelling or letter string using a simple sentence cue. The study also included a control group matched for reading level. The results revealed a similar degree of orthographic facilitation during learning and in a post-training picture naming task in both the control and Down syndrome groups.

Lucas and Norbury (2014) examined whether children with autism spectrum disorders (ASD) and typically developing children benefited to a similar degree from the presence of orthography while learning 16 low-frequency secondary-school level science words. Similar to previous studies, a paired-associate word learning task was used. The semantic information provided was that of 'semantic category' (i.e. 'plant related' or 'animal related'), and the children were exposed to the words only twice in order to avoid ceiling effects. The ASD group showed a greater degree of orthographic facilitation than the control group, and eye tracking results revealed that the children with ASD actively searched for the spellings while learning words. Learning of semantic category was not assessed after the training phase. Also, the benefit persisted when tested one day after the word learning experiment. In a recent study Ricketts et al. (2015), further explored orthographic facilitation for spoken word learning in children with specific language impairment (SLI), ASD, and typical development. The

experiment was conducted using the same paradigm as Ricketts et.al (2009). All three groups benefitted equally from the presence of orthography. Thus, the concept of orthographic facilitation of vocabulary acquisition has empirical support in different populations, including children with typical development, Down Syndrome, SLI and ASD.

The Present Study.

As previously described, there is evidence for orthographic facilitation of vocabulary acquisition in special populations, including children with ASD, Down syndrome and SLI (Lucas et al., 2014; Mengoni et al., 2013; Ricketts et al., 2015). However, the presence of an orthographic facilitation effect in children with hearing loss remains to be explored.

The possible facilitatory influence of orthographic information is of particular relevance in the context of children with hearing loss, whose marked difficulty in learning new spoken words presumably reflects, at least in part, the need to extract word-level phonology and hold it in short-term memory for long enough to form a link with meaning. As a consequence of their phonological deficits (Park & Lombardino, 2012), an additional cognitive load is placed on children with hearing loss, when they are attempting to learn a new spoken word, which could therefore result in a failure to establish a link between phonology and semantics (Panel A, Figure 3).

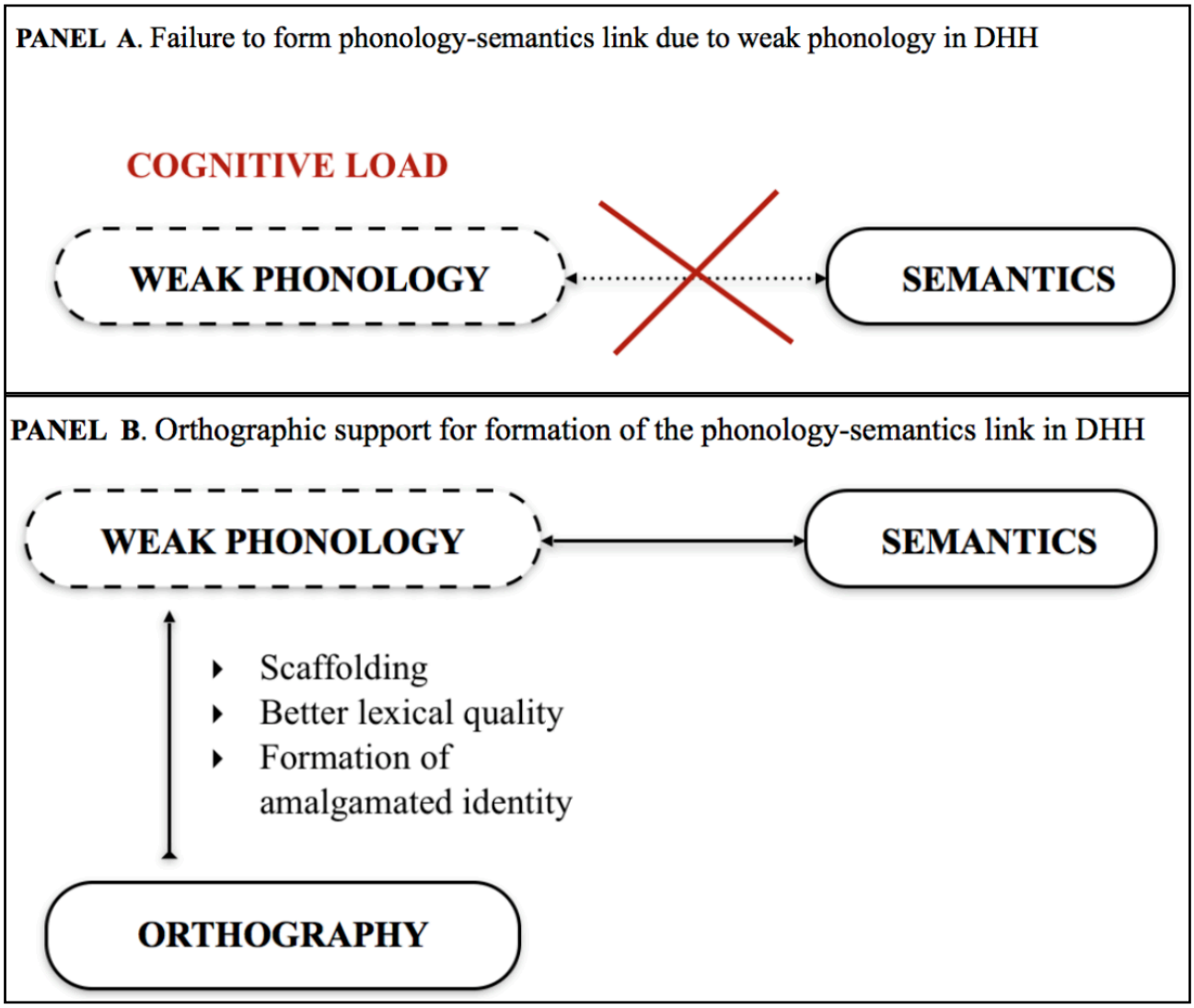

Figure 3. The formation of the phonology-semantics link in DHH children

In contrast to auditorily presented information, however, orthography is less transient and provides a mechanism for children to confirm the pronunciation of a new word, thereby reducing the cognitive load (Ehri & Rosenthal, 2007). This may be of particular benefit to DHH children, given their weak phonological skills. The lexical quality hypothesis (Perfetti et al., 2001) and the word amalgamation theory (Ehri, 1978) further support the idea that having additional orthographic support could be particularly beneficial for word learning in DHH children. Orthography could potentially provide the necessary scaffolding for phonology and

therefore facilitate the formation of the phonology-semantics link for successful word learning in these children (Panel B, Figure 3).

The present study aimed to provide evidence for orthographic facilitation of vocabulary learning in orally communicating DHH children, following the design of Ricketts et al. (2009). Primary school children with hearing loss were given novel vocabulary items to learn either in the presence or absence of orthography. We hypothesised that children would benefit from the incidental presence of orthography in this word learning paradigm (i.e., following Ricketts et al.).

Method

Participants

Participants were 14 children aged 7 - 12 years (*M* age = 8 years; 10 months, *SD* = 16 months) who had varying degrees of hearing loss, ranging from mild to profound (Appendix A). All the children used hearing aids or cochlear implants in both ears. They were recruited from a school for children with significant hearing loss in the region of Sydney, Australia. The school follows the regular curriculum with intensive intervention in speech and language development as required. Because the school aims to prepare the students for full inclusion in a regular school, they all attend a local mainstream school for a part of each day. Consent forms were distributed to the families of 16 children who fit the age criteria for the study; 14 consented to take part.

Standardised tests

Standardised measures of language and vocabulary were obtained from school records. These included the Clinical Evaluation of Language Fundamentals (CELF- 4; Semel, Wiig, & Secord., 2006) and the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007). Reading ability was assessed using the Castles & Coltheart 2 (CC2; Castles, Coltheart, Larsen, Jones, Saunders & McArthur, 2010). The CC2, which was administered individually, assesses

single word reading using 40-word lists of regular, irregular and nonwords. These tests were included to determine whether orthographic facilitation observed in the participants was dependent on their language and reading abilities. Additionally, reports of the Diagnostic Evaluation of Articulation and Phonology (DEAP) were obtained from school records in order to determine any speech errors exhibited by the participants. A summary of scores obtained on standardised measures is provided in Table 1.

Table 1

Participants' age and performance on standardised tests.

	M	SD	Min	Max
Age	8;10	16 months	7;11	12;0
Language (CELF-4)				
Receptive language [a]	73.40	15.01	52	98
Expressive language [a]	74.00	17.89	49	100
Vocabulary (PPVT) [b]	84.10	19.22	50	118
Reading ability (CC2) [c]				
Regular words	32.50	7.833	11	38
Irregular words	19.67	5.348	6	29
Nonwords	26.33	10.06	6	37

Note: CELF - 4, The Clinical Evaluation of Language Fundamentals; PPVT-4, Peabody Picture Vocabulary Test ; CC2, Castles & Coltheart 2.

[a]Standard scores; [b]Standard scores; [c]Raw scores (Total=40)

Experimental materials

Twelve nonwords containing 3 or 4 letters were chosen from previous studies (Ricketts et al.,2009; Wang, Castles, Nickles & Nation, 2011). These items were paired with pictures

used to study orthographic facilitation by Ricketts et al. (2009). The referents were pictures of unusual 3D objects, which they child was unlikely to have ever encountered. At the beginning of the experiment, it was explained to participants that they would learn the names some new things. Things that an alien may use in a spaceship. An example stimulus is provided in Figure 4.

furd

Figure 4. Example of an a nonword-picture pair used in the experiment

The stimuli were divided into 2 groups of 6 items each and presented in two conditions, orthography present and orthography absent. For the orthography present condition, the written word was printed above the picture, in black Arial regular font, 30-point size. Assignment of items to the two orthography conditions was counterbalanced across participants. Table 2 shows the full set of items used in the experiment.

Table 2

Experimental stimuli

Item number	Phonology	Orthography
1	/dʒiːl/	jeal
2	/daʊd/	doud
3	/həʊt/	hote
4	/miːm/	meem
5	/væk/	vack
6	/lɔːk/	lork
7	/nɔːn/	nawn
8	/fɜːd/	furd
9	/preɪf/	praif
10	/gəʊk/	goak
11	/cliːp/	cleap
12	/sɜːn/	sern

The word-learning paradigm

For direct comparison and consistency with previous studies of orthographic facilitation of spoken word acquisition, the word learning paradigm used in previous studies was incorporated (eg., Ricketts et al., 2009). Non word stimuli and pictures of novel 3D objects (Ricketts et al., 2009) to ensure that the words were not already a part of the participants' lexicon.

Learning phase. A paired-associate word learning task was employed to teach children the nonwords. The experiment was conducted in individual sessions, in a quiet room within the school premises. The children learned the 12 nonword-picture pairings across two days, 6 items

per day (3 in each orthography condition). Coloured pictures of the unfamiliar objects were printed onto individual cards. For stimuli in the orthography present condition, the spelling of the nonword was printed above the picture, on the card. Children were assigned alternatively to Set 1 or Set 2. Set 1 children learned the first 6 items in the orthography present condition while Set 2 children learned the second 6 items in the orthography present condition.

The children were first told that they would see pictures of new objects and would be learning their names. The training consisted of 3 blocks. Each block included one repetition and one production task. For the repetition task, the experimenter showed the picture and named it, and the child was instructed to repeat the name after the experimenter. After completing the repetition task for the 6 pictures, the child completed the production task, in which they were required to try and say the name of each picture in the same sequence as the repetition task. The child received feedback after each item; the experimenter showed the picture again (with or without the spelling based on the orthography condition) and provided the label. Thus, in every block the child was exposed to the picture four times and heard the nonword three times. This procedure was repeated two more times (Fig. 5). Performance on the production task was used to measure word learning in each block. Reports of the Diagnostic Evaluation of Articulation and Phonology (DEAP) were obtained from school records and taken into consideration while scoring the audio-recorded responses of the participants. If errors on particular phonemes were in the DEAP test, then those were taken as correct responses in the test. For example, according to the DEAP report participant 13 exhibited cluster reductions and replaced 'w' for 'r', Thus, the response 'pwaif' instead of 'praif' was accepted as a correct response for this participant. However, such instances were very few among the students who participated in this experiment.

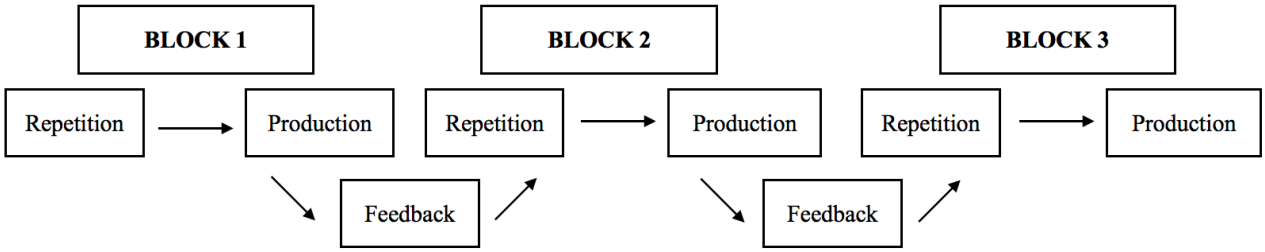

Figure 5. The word learning paradigm.

Testing phase. A nonword-picture matching test was conducted immediately after each training session, on both days, using the Psyscope X B77 program on a laptop. The children listened to a nonword, spoken by the experimenter, and then saw four previously trained pictures on the screen. They were asked to match the nonword to the correct picture using the laptop keys (Figure 6).

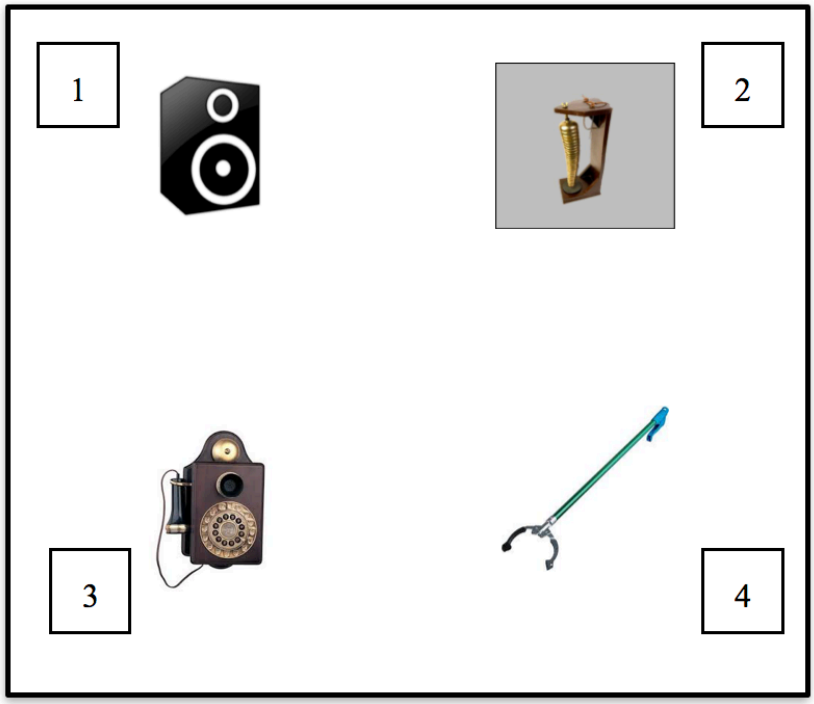

Figure 6. Nonword-picture matching task

For easy access, four keys on the laptop had been labelled with the numbers 1 - 4, corresponding to the pictures on the screen. Response accuracy and reaction times were recorded by the software. Two practice trials using pictures of common objects were provided

at the beginning to familiarise the children with the task. At the end of Day 1, learning of the 6 taught nonwords was assessed using a nonword-picture matching task. On Day 2, the children were taught another 6 words. At the end of Day 2, learning of all 12 nonwords was assessed using a nonword-picture matching task. Finally, spelling was also assessed.

Spelling. Following the nonword-picture matching task, the experimenter dictated the nonwords one by one. The child was asked to write down the spellings of the nonwords on the form provided. This task provided a means to check whether the children had acquired knowledge about the spellings of the written words from the brief incidental exposure during the word learning experiment. Responses were categorised as correct or incorrect, and a spelling accuracy score was calculated.

Results

Learning Phase

For the purpose of the analysis, data from the two days were combined and learning of all 12 nonwords was examined. Performance on the production task in each block was taken as a measure of learning. Children were able to perform this task quite well, producing a proportion of 0.75 (range: 0.33-1) items correctly on average at the end of training block 3. As

shown in Figure 7, learning gradually improved across blocks, and learning appeared to be consistently better for the words in the orthography present condition.

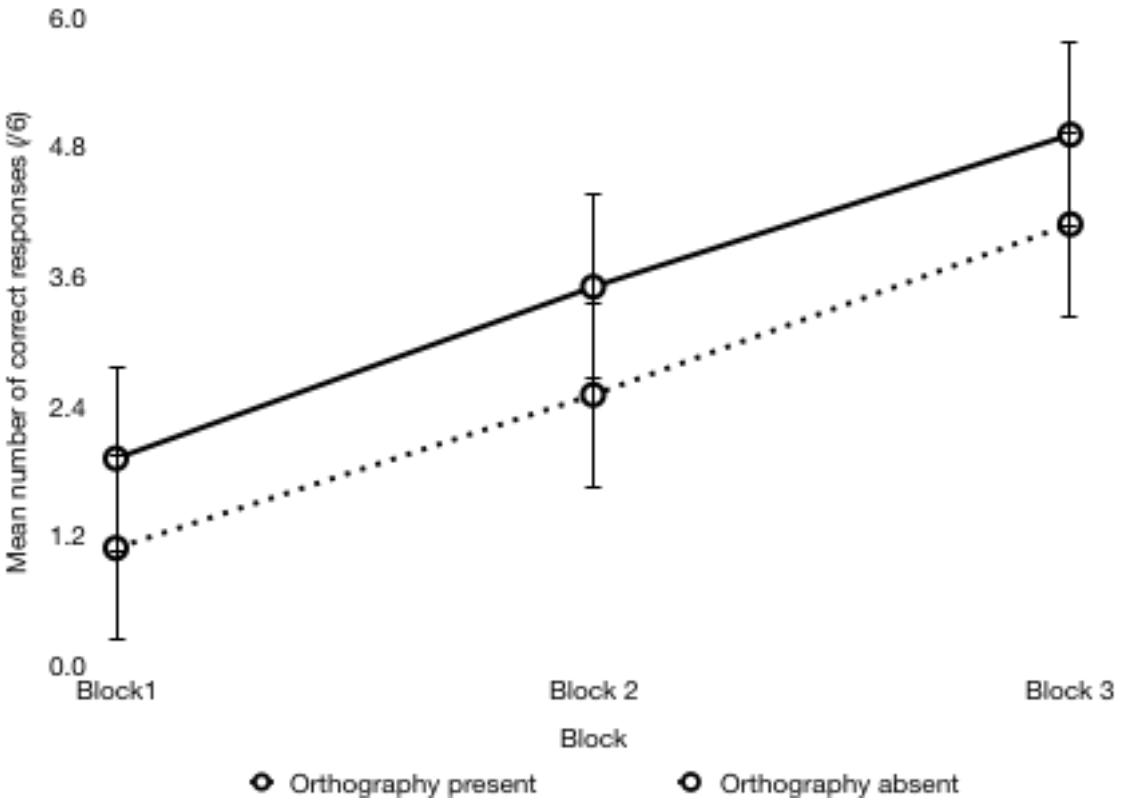

Figure 7. Performance on production task across 3 blocks in the 2 orthography conditions

To examine whether orthography influenced learning across the blocks, a 2x3 Analysis of Variance was conducted with Orthography (present vs. absent) and Block (1 vs. 2 vs. 3) as repeated measures. Significant main effects were obtained for both Orthography conditions, $F(1,13) = 9.01, p=0.01, \eta^2 = .41$ and block $F(2,26) = 55.89, p<.001, \eta^2 = .81$ but not for the Orthography x Block interaction, $F(2,26) = .23, p=.79, \eta^2= .01$. As the data were not normally distributed, a nonparametric test, the Wilcoxon Signed Rank test, was conducted to verify the results obtained using ANOVA. The difference in naming accuracy between the two orthography conditions during the production task, was significant in blocks 2, $z= 2.22, p=.02$ and 3, $z=2.22, p= .02$ and marginally significant in block 1, $z=1.90, p = .05$.

Testing Phase

The testing phase consisted of the nonword-picture matching task and the spelling test. Table 3 shows participants' scores on the two tasks as a function of orthography condition.

Table 3

Performance on experimental parameters

	Orthography present				Orthography absent		
	M	SD	Min	Max	M	SD	Min
Nonword-picture matching task [1]							
Accuracy	5.28	1.48	1	6	5.35	1.15	3
Reaction time	2926	851	1466	4474	3128	1364	1228
Spelling accuracy [1]	3.25	2.05	0	6	0.5	0.67	0

Note: The table displays raw scores. [1] *Six items*

Nonword-picture matching tas*k*. Accuracy and reaction time data were collected for the nonword-picture matching task. Participants were slightly more accurate on this task for words learned in the orthography absent condition. However, the difference between accuracy in the orthography present (M=5.28, SD=1.48) and orthography absent (M=5.35, SD= 1.15) conditions was not statistically significant; $t(13)$= -0.32, p=0.75.

For the analysis of reaction time, only the reaction times for correct responses were included. Therefore, 13.19% of the RTs, corresponding to incorrect responses were excluded from the analysis. The participants appeared to be generally slow to perform the task, although variability is evident in this measure. Participants produced correct responses faster for words

taught with orthography than without. However, there was no statistically significant difference in mean reaction times for the orthography present and orthography absent conditions, $t(13) = -0.74$, $p=0.47$.

Spelling. The spellings produced by the participants were scored as correct or incorrect according to the target spellings as provided in the orthography present condition during training (Table 2). Children spelled the words learned in the orthography present condition more accurately than in the orthography absent condition. There was a statistically significant difference in these scores, indicating that the children did learn about the orthography of the nonwords from the brief exposure to their spellings during the training phase, $t(13)= 4.750$, $p<.001$.

Orthographic Facilitation. As described earlier, children's performance on the production task during the learning phase differed significantly between the two orthography conditions, across blocks. In order to quantify this facilitatory effect, an orthographic facilitation (OF) measure was obtained across the training period. The difference in mean accurate naming responses between the orthography present and absent conditions was calculated, yielding an OF value for each block (Table 4).

Table 4

Orthographic facilitation

	M	SD
Block 1	0.83	1.00
Block 2	1.70	1.28
Block 3	0.83	1.00

The Wilcoxon Signed Rank test showed that there was no significant difference in the orthographic facilitation between Block 1 and Block 2 (Z= -0.54, *p*=0.58), Block 2 and Block 3 (Z=-0.49, *p*=0.62) or Block 1 and Block 3 (Z=-0.05, *p*=0.95). To examine individual variation, the orthographic learning effect was examined for each participant separately across the blocks. The results are presented in Figure 8. As the figure shows, 12 participants displayed a numerical facilitatory effect at some point during training. However, there was considerable variation in when the benefit emerged. For participants 1, 2, 3, 4, 8, 13, and 14, facilitation was evident immediately after the first exposure (Block 1). In contrast, for participants 5, 6, 10 and 12, OF emerged at the end of training. Participant 11 experienced no facilitation during learning, and the presence of orthography appeared to interfere with, rather than facilitate, learning for participant 9.

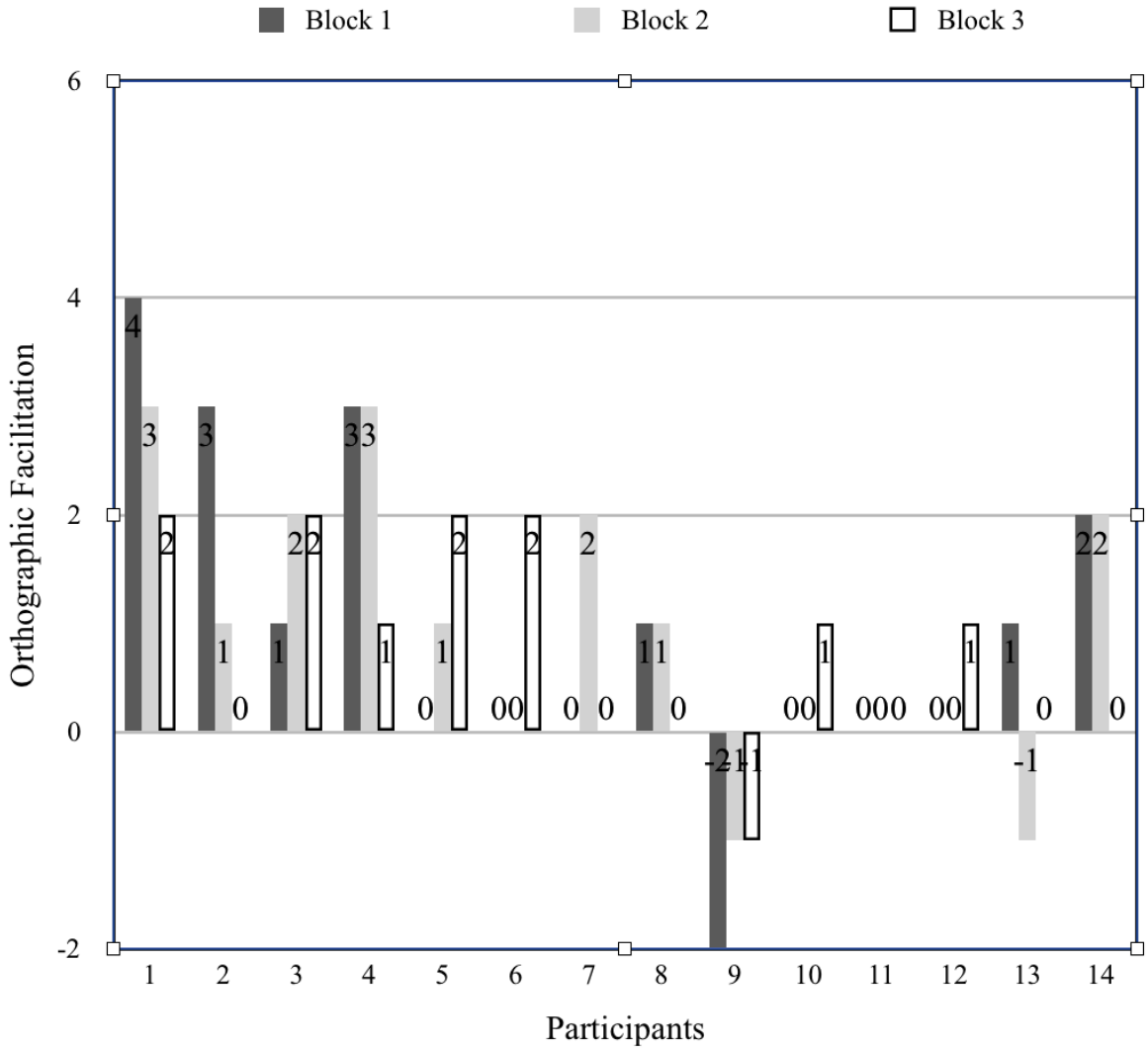

Figure 8. Orthographic facilitation across participants

Correlations with background measures

The outcome measures for the learning and testing phase were correlated with background measures including receptive and expressive language, vocabulary, and reading (regular, irregular and nonwords) using Spearman's rank order correlation coefficients. None of the background measures correlated with orthographic facilitation for picture naming accuracy during training, nonword-picture matching accuracy, or reaction time (Figure 9). However, the ability to learn spellings in the orthography present condition was related to the children's reading ability. The difference in spelling accuracy between the two orthography

conditions, correlated significantly with regular word reading ($r_s = 0.644, p = 0.024$), irregular word reading ($r_s = 0.592, p = 0.042$) and nonword reading ($r_s = 0.611, p = 0.035$).

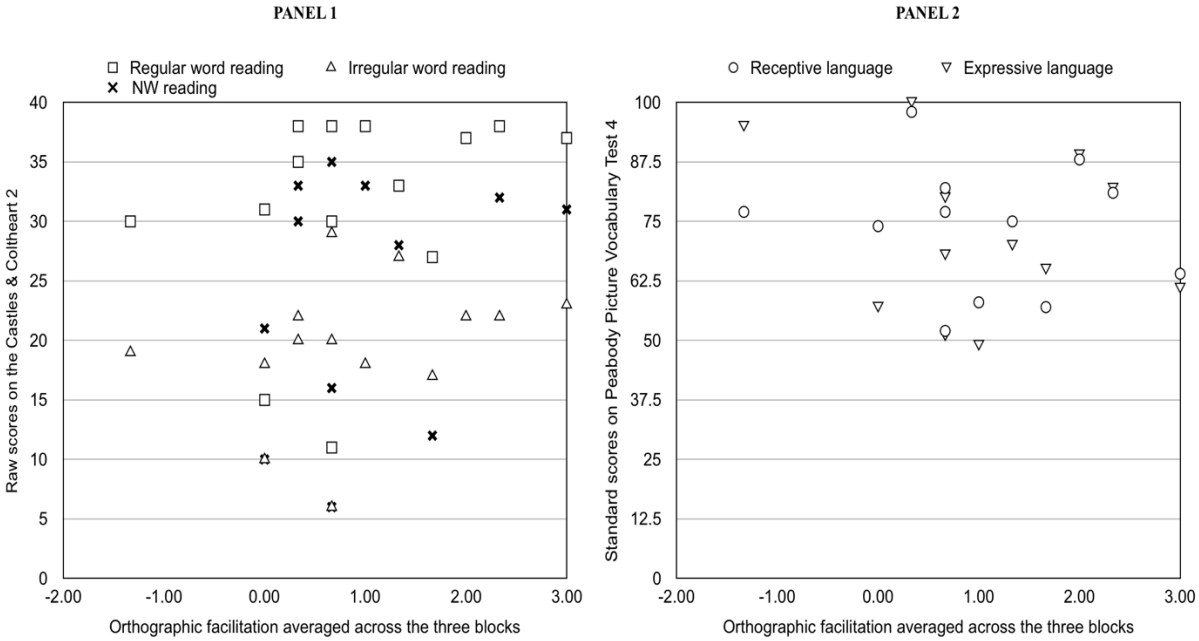

Figure 9. Scatterplot of performance on language and reading tests versus orthographic facilitation scores, averaged over the three blocks

Discussion

The present study aimed to investigate whether orthography can support oral vocabulary learning in children with hearing loss. A likely cause of spoken-word learning difficulties faced by children with hearing loss is weak phonological skills and/or poor phonological working memory. In accordance with this possibility, and the growing evidence for orthographic facilitation of oral vocabulary development in children with typical development (e.g., Ricketts et al., 2009) and various forms of developmental disability (e.g., Ricketts et al., 2015), we hypothesised that children with hearing loss would benefit from the presence of spellings while learning new spoken words. Further, drawing from the lexical quality hypothesis and the word identity amalgamation theory, we expected that spellings would help to better secure the pronunciations of the new words in memory for these children. To examine this hypothesis, 14 children with hearing loss were taught 12 novel-word-picture

pairs using a paired-associate word learning paradigm, over two days. The results of the study are discussed in light of previous literature.

During the learning phase, naming accuracy on the picture-naming task was significantly better for words learned with spellings than without, thereby indicating that orthography facilitated word learning in our sample of children with hearing loss. This result is consistent with previous studies that show a facilitatory influence of orthography on the learning of words' pronunciations in children with typical and atypical development (Jubenville, 2012; Lucas & Norbury, 2014; Mengoni et al., 2013; Ricketts et al., 2009; Ricketts et al., 2015; Rosenthal & Ehri, 2008). An orthographic facilitation measure was obtained for each training block by measuring the difference in naming accuracy on the production task. The lack of difference in the degree of facilitation across the three blocks can be attributed to individual variability in the onset of orthographic facilitation. While some children immediately derived benefits from the incidental presence of spelling, others were more gradual in making use of the spellings. However, for one participant (9) the presence of spelling appeared to hinder word learning. This participant is known to have Attention Deficit Hyperactivity Disorder, where processing of multiple stimuli is often a challenge (Corbett & Constantine, 2006; Dionne-Dostie, Paquette, Lassonde, & Gallagher, 2015). The incidental presence of the spelling, along with the picture and the auditory stimulus, may have distracted this child from learning the pronunciation of the words presented with spellings. Overall, our results suggest that orthography facilitates spoken word learning in children with hearing loss, at least during the active learning phases.

Contrary to expectation, the presence of orthography did not result in significantly better performance on the nonword-picture matching post-test. Although the children were numerically faster in making accurate responses for words learned with spellings than without, this difference was not statistically significant. A number of other studies have used a similar

measure to assess orthographic facilitation of nonword learning (Lucas et al., 2014; Ricketts et al., 2009; Ricketts et al., 2015), and the findings have been mixed. In two studies, Ricketts et al. (2009) which tested children with typical development, and Ricketts et al. (2015) which tested children with typical development, ASD and SLI, accuracy on the nonword-picture matching task was not analysed as the scores were at ceiling; however, they did find a significant difference in reaction time between the words learned in the orthography present vs. orthography absent conditions. In Ricketts et al. (2015), this effect was similar for children with SLI and children with typical development. Contrastingly, Lucas et al. (2014) reported that a group of children with ASD showed greater accuracy on the word-picture matching task for words learned with orthography, whereas no such effect was observed for typically developing children.

The nature of the nonword-picture matching task is such that the child is required to access meaning (the picture of the novel object) on hearing the novel word. It would appear from the current results that learning in the presence of spellings speeds up this access to meaning, but that spellings are not absolutely necessary for children with hearing loss to form a link between phonology and semantics. This lack of an effect of orthography condition on accuracy in the nonword picture matching task at post-test, despite a significant effect during training may need to be further explored in future studies. Interestingly, there is evidence for orthographic support for learning meanings and recall of definitions of new words (Rosenthal & Ehri, 2008). In our study, the meaning of the novel word was represented by the picture alone. It may be worthwhile to examine orthographic facilitation for word learning in more semantically-rich contexts, which would better depict a natural word learning situation. Another interesting line of research would be to examine how orthography supports learning of meanings and pronunciations of words that are less picturable.

The results of the spelling to dictation post-test provide additional evidence that despite brief incidental presentation, the children were able to learn the spellings of the words in the orthography present condition. For the sake of simplicity, this initial study did not manipulate spelling-to-sound consistency of the nonword stimuli. It would be worthwhile to examine whether consistency affects the facilitation of word learning observed children with hearing loss. Given that children may use spelling as a checking mechanism to confirm the auditory input (Ehri, 1987; Rosenthal & Ehri, 2008), it is plausible that a discrepancy between the two may lead to confusion, especially in this population.

In an effort to understand the substantial individual variation that was observed between participants in the degree of orthographic facilitation, we examined its association with language and reading abilities. Orthographic facilitation for spoken word learning measured during the learning phase did not correlate with receptive language, expressive language, or any of the reading measures (regular, irregular or nonword reading). This result is in contrast to previous studies which reported that children with better reading abilities benefit more from the presence of spellings during spoken word learning (Rosenthal & Ehri 2008). Since there was no difference in accuracy on the nonword-picture matching task, those results were not compared with background measures of the participants in this study. Ricketts et al (2009) did not find an effect of language and reading abilities during training tasks such as those used here, which required repetition and picture-naming. However, better readers showed greater orthographic facilitation in the nonword-picture matching and spelling post-tests. We found similar results on the spelling-to-dictation task; regular, irregular and nonword reading abilities significantly correlated with the difference in spelling accuracy between the orthography present and orthography absent conditions. From these results, we infer that children with hearing loss who are better readers are able to better learn spellings incidentally than those who are poorer readers. However, more detailed assessments would be required to explore the

relations between orthographic facilitation and the reading abilities of children with hearing loss.

One limitation of this study is the small sample size. Given the great variability between participants, a larger sample size would be required to draw strong conclusions regarding the association between orthographic facilitation and language and reading abilities. We have demonstrated the variance in the orthographic facilitation of vocabulary learning among our participants. A larger sample size is required to examine the effects of degree of hearing loss and hearing device usage, and whether these factors could explain the variation observed in the orthographic facilitation in children with hearing loss. Another limitation is that the ceiling effects were not accounted for. In addition, including a larger number of post-test assessments such as a picture-naming test could be advantageous to assess children's ability to access phonology from semantics. Also, in the present study, vocabulary acquisition was defined as the acquisition of a phonology-semantics link. It is of equal importance to examine the retention of newly-learned words. Therefore, future studies could examine the extent to which orthography helps to secure the pronunciations of new words in memory over a more extended period of time. Another area of interest would be to manipulate the orthographic consistency of the words and observe the effect on orthographic facilitation in this population.

Conclusion

In conclusion, this study provides evidence for orthographic facilitation of spoken word learning in children with hearing loss during the learning process, thus extending the existing literature on orthographic facilitation for oral vocabulary acquisition to this new population (Jubenville, 2012; Lucas et al., 2014; Mengoni et al., 2013; Ricketts et al., 2009; Ricketts et al., 2015; Rosethal et al., 2008). Children were able to learn pronunciations of nonwords better in the presence of orthography than in its absence, even though no attention was drawn to the spellings in the word learning paradigm. However, the beneficial effect during learning could

not be demonstrated on post-test measures. Given that oral vocabulary acquisition is challenging for children with hearing loss (e.g. Hermans et al., 2015), the identification of factors that support word learning is of utmost importance in the field of deaf education. These results prompt the further investigation of this effect in a larger population of children with hearing loss.

Chapter 3

References

References

Akhtar, N., & Gernsbacher, M. A. (2007). Joint Attention and Vocabulary Development: A Critical Look. *Language and Linguistics Compass*, *1*(3), 195–207. https://doi.org/10.1111/j.1749-818X.2007.00014.x

Aitchison, J. (1994). *Words in the Mind: An Introduction to the Mental Lexicon* (2nd ed.), Oxford, Blackwell.

Alishahi, A., Fazly, A., & Stevenson, S. (2008). Fast Mapping in Word Learning: What Probabilities Tell Us. In *Proceedings of the Twelfth Conference on Computational Natural Language Learning* (pp. 57–64). Stroudsburg, PA, USA: Association for Computational Linguistics. Retrieved from http://dl.acm.org/citation.cfm?id=1596324.1596335

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, *105*(1), 158–173.

Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference*. *Journal of Child Language*, *20*(2), 395–418. https://doi.org/10.1017/S0305000900008345

Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Irwin, J. M., & Tidball, G. (1996). Infants' reliance on a social criterion for establishing word-object relations. *Child Development*, *67*(6), 3135–3153.

Baldwin, D. A., & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development, 10*(3), 309-329. http://dx.doi.org/10.1111/1467-9507.00168

Barker, L. J. (2003). Computer-Assisted Vocabulary Acquisition: The CSLU Vocabulary Tutor in Oral-Deaf Education. *The Journal of Deaf Studies and Deaf Education*, *8*(2), 187–198. https://doi.org/10.1093/deafed/eng002

Barrett, M. D. (1986). Early Semantic Representations and Early Word-Usage. In *The Development of Word Meaning* (pp. 39–67). Springer, New York, NY. https://doi.org/10.1007/978-1-4612-4844-6_2

Beck, I. L., McKeown, M. G., & Kucan, L. (2013). *Bringing words to life: Robust vocabulary instruction*. New York: Guilford Press.

Benasich, A. A., & Tallal, P. (2002). Infant discrimination of rapid auditory cues predicts later language impairment. *Behavioural brain research*, *136*(1), 31-49. https://doi.org/10.1016/S0166-4328(02)00098-0

Biemiller, A. (2006). Vocabulary development and instruction: A prerequisite for school learning. *Handbook of early literacy research*, *2*, 41-51. Retrieved November 22, 2017, from http://web.b.ebscohost.com/ehost/detail/detail?vid=0&sid=44944982-68a1-468a-956f-5d91f76619da%40sessionmgr120&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d

Biemiller, A., & Boote, C. (2006). An effective method for building meaning vocabulary in primary grades. *Journal of Educational Psychology, 98*(1), 44-62. http://dx.doi.org/10.1037/0022-0663.98.1.44

Bloom, L. (1976). *One word at a time: The use of single-word utterances before syntax*. The Hague. Retrieved from https://academiccommons.columbia.edu/catalog/ac:205196

Bloom, L., & Markman, L. (1998). Capacities underlying word learning - ScienceDirect. Retrieved November 22, 2017, from

Bloom, P., & Markson, L. (2001). Are there principles that apply only to the acquisition of words? A reply to Waxman and Booth. *Cognition, 78*(1), 89-90. http://dx.doi.org/10.1016/S0010-0277(00)00111-6

http://www.sciencedirect.com/science/article/pii/S1364661398011218

Booth, A. E., & Waxman, S. R. (2003). Bringing theories of word learning in line with the evidence. *Cognition*, *87*(3), 215–218.

Burger, A., & Chong, I. (2011). Receptive Vocabulary. In S. Goldstein & J. A. Naglieri (Eds.), *Encyclopedia of Child Behavior and Development* (pp. 1231–1231). Springer US. https://doi.org/10.1007/978-0-387-79061-9_2359

Carey, S., & Bartlett, E. (1978). Acquiring a Single New Word.

Castles, A., Coltheart, M., Larsen, L., Jones, P., Saunders, S., & McArthur, G. (2009). Assessing the basic components of reading: A revision of the Castles and Coltheart test with new norms. *Australian Journal of Learning Difficulties*, *14*(1), 67-88. https://doi.org/10.1080/19404150902783435

Chambré, S. J., Ehri, L. C., & Ness, M. (2017). Orthographic facilitation of first graders' vocabulary learning: does directing attention to print enhance the effect? *Reading and Writing*, 1–20. https://doi.org/10.1007/s11145-016-9715-z

Chapman, R. S. (2000). Children's Language Learning: An Interactionist Perspective. *Journal of Child Psychology and Psychiatry*, *41*(1), 33–54. https://doi.org/10.1111/1469-7610.00548

Corbett, B. A., & Constantine, L. J. (2006). Autism and Attention Deficit Hyperactivity Disorder: Assessing Attention and Response Control with the Integrated Visual and Auditory Continuous Performance Test. *Child Neuropsychology*, *12*(4–5), 335–348. https://doi.org/10.1080/09297040500350938

Coyne, M. D., McCoach, D. B., Loftus, S., Zipoli, R., & Kapp, S. (2009). Direct Vocabulary Instruction in Kindergarten: Teaching for Breadth versus Depth. *The Elementary School Journal*, *110*(1), 1–18. https://doi.org/10.1086/598840

de Jong, P. F., Seveke, M. J., & van Veen, M. (2000). Phonological sensitivity and the acquisition of new words in children. *Journal of Experimental Child Psychology*, *76*(4), 275–301. https://doi.org/10.1006/jecp.1999.2549

Dickinson, D. (1920). The Importance of Vocabulary in Reading. *The Elementary School Journal*, *20*(7), 537–546. Retrieved from http://www.jstor.org/stable/993922.

Dionne-Dostie, E., Paquette, N., Lassonde, M., & Gallagher, A. (2015). Multisensory Integration and Child Neurodevelopment. *Brain Sciences*, *5*(1), 32–57. https://doi.org/10.3390/brainsci5010032

Dobie, R. A., & Van Hemel, S., (2004) Hearing Loss: Determining Eligibility for Social Security Benefits. *In National Research Council (US) Committee on Disability Determination for Individuals with Hearing Impairments*. Washington (DC): National Academies Press (US); 2004. 7, Hearing Loss in Children. Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK207837/

Dockrell, Julie E., and David Messer. "Lexical acquisition in the early school years." *Language development across childhood and adolescence* 3 (2004): 35-52.

Dunn, D. M., & Dunn, L. M. (2007). *Peabody picture vocabulary test: Manual*. Pearson.

Easterbrooks, S. & Beal-Alvarez, J. (2013). Literacy instruction for students who are deaf and hard of hearing: Professional perspectives on deafness, evidence and applications. NY: Oxford

Ehri, L. C. (2014). Orthographic Mapping in the Acquisition of Sight Word Reading, Spelling Memory, and Vocabulary Learning. *Scientific Studies of Reading*, *18*(1), 5–21. https://doi.org/10.1080/10888438.2013.819356

Ehri, L. C., & Rosenthal, J. (2007). Spellings of Words: A Neglected Facilitator of Vocabulary Learning. *Journal of Literacy Research*, *39*(4), 389–409. https://doi.org/10.1080/10862960701675341

Ehri, L. C., & Wilce, L. S. (1979). The mnemonic value of orthography among beginning readers. *Journal of Educational Psychology*, *71*(1), 26–40.

Ellis, L. C.,. (1997). Vocabulary acquisition: Word structure, collocation, grammar, and meaning. In M. McCarthy & N.Schmidt (Eds.), *Vocabulary: description, acquisition and pedagogy*. Cambridge: Cambridge University Press.

Fazly, A., Alishahi, A., & Stevenson, S. (2010). A probabilistic computational model of cross-situational word learning. *Cognitive Science*, *34*(6), 1017–1063. https://doi.org/10.1111/j.1551-6709.2010.01104.x

Ferguson, B., & Waxman, S. R. (2016). What the [beep]? Six-month-olds link novel communicative signals to meaning. *Cognition*, *146*, 185–189. https://doi.org/10.1016/j.cognition.2015.09.020

Gathercole, S., & Baddeley, A. (1993). *Working memory and language*. Hove, England: Erlbaum.

Gathercole, S. E., Hitch, G. J., Service, E., & Martin, A. J. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology, 33*(6), 966-979. http://dx.doi.org/10.1037/0012-1649.33.6.966

Geers, A. E. (2006). Factors influencing spoken language outcomes in children following early cochlear implantation. *Advances in Oto-Rhino-Laryngology*, *64*, 50–65. https://doi.org/10.1159/000094644

Gupta, P., & Tisdale, J. (2009). Word learning, phonological short-term memory, phonotactic probability and long-term memory: towards an integrated framework. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1536), 3755–3771. https://doi.org/10.1098/rstb.2009.0132

Hayes, H., Geers, A. E., Treiman, R., & Moog, J. S. (2009). Receptive Vocabulary Development in Deaf Children with Cochlear Implants: Achievement in an Intensive Auditory-Oral Educational Setting. *Ear & Hearing*, *30*(1), 128–135. https://doi.org/10.1097/AUD.0b013e3181926524

He, A. X., & Arunachalam, S. (2017). Word learning mechanisms. *Wiley Interdisciplinary Reviews. Cognitive Science*. https://doi.org/10.1002/wcs.1435

Hermans, D., Wauters, L., Willemsen, M., & Knoors, H. (2015). Vocabulary Acquisition in Deaf and Hard-of-Hearing Children. https://doi.org/10.1093/oxfordhb/9780190241414.013.11

Hoff, E. and Naigles, L. (2002), How Children Use Input to Acquire a Lexicon. Child Development, 73: 418–433. doi:10.1111/1467-8624.00415

Hollich, G. J., Hirsh-Pasek, K., Golinkoff, R. M., Brand, R. J., Brown, E., Chung, H. L., Rocroi, C. (2000). Breaking the language barrier: an emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development*, *65*(3), i–vi, 1-123.

Horst, J. S., & Samuelson, L. K. (2008). Fast Mapping but Poor Retention by 24-Month-Old Infants. *Infancy*, *13*(2), 128–157. https://doi.org/10.1080/15250000701795598

Houston, D. M., Carter, A. K., Pisoni, D. B., Kirk, K. I., & Ying, E. A. (2005). Word Learning in Children Following Cochlear Implantation. *The Volta Review*, *105*(1), 41–72.

Houston, D. M., Stewart, J., Moberly, A., Hollich, G., & Miyamoto, R. T. (2012). Word learning in deaf children with cochlear implants: effects of early auditory experience. *Developmental Science*, *15*(3), 448–461. https://doi.org/10.1111/j.1467-7687.2012.01140.x

Hulme, C., Goetz, K., Gooch, D., Adams, J., & Snowling, M. J. (2007). Paired-associate learning, phoneme awareness, and learning to read. *Journal of Experimental Child Psychology*, *96*(2), 150–166. https://doi.org/10.1016/j.jecp.2006.09.002

James, D., Rajput, K., Brinton, J., & Goswami, U. (2008). Phonological Awareness, Vocabulary, and Word Reading in Children Who Use Cochlear Implants: Does Age of Implantation Explain Individual Variability in Performance Outcomes and Growth? *The Journal of Deaf Studies and Deaf Education*, *13*(1), 117–137. https://doi.org/10.1093/deafed/enm042

Johnson, C., & Goswami, U. (2010). Phonological Awareness, Vocabulary, and Reading in Deaf Children With Cochlear Implants. *Journal of Speech, Language, and Hearing Research*, *53*(2), 237–261. https://doi.org/10.1044/1092-4388(2009/08-0139)

Jubenville, K. (2012). Crossing modalities to support word-learning : incidental orthographic facilitation in oral vocabulary acquisition. Retrieved April 11, 2017, from https://curve.carleton.ca/693f9e21-8013-4927-a472-43788669f174

Jusczyk, P. W., & Aslin, R. N. (1995). Infants' detection of the sound patterns of words in fluent speech. *Cognitive Psychology*, *29*(1), 1–23. https://doi.org/10.1006/cogp.1995.1010

Kaefer, T. (2016). Integrating Orthographic and Phonological Knowledge in Early Readers: Implicit and Explicit Knowledge. https://doi.org/10.1155/2016/6036129

Kirk, K. I., Miyamoto, R. T., Lento, C. L., Ying, E., O'Neill, T., & Fears, B. (2002). Effects of age at implantation in young children. *The Annals of Otology, Rhinology & Laryngology. Supplement*, *189*, 69–73. https://doi.org/10.1177/00034894021110S515

Hansen, B. M., & Markman, M. E. (2009). *Children's Use of Mutual Exclusivity to Learn Labels for Parts of Objects* (Vol. 45). https://doi.org/10.1037/a0014838

Harris, M., & Beech, J. R. (1998). Implicit Phonological Awareness and Early Reading Development in Prelingually Deaf Children. *The Journal of Deaf Studies and Deaf Education*, *3*(3), 205–216. https://doi.org/10.1093/oxfordjournals.deafed.a014351

Kim, Y.S. G. (2017). Multicomponent view of vocabulary acquisition: An investigation with primary grade children. *Journal of Experimental Child Psychology*, *162*(Supplement C), 120–133. https://doi.org/10.1016/j.jecp.2017.05.004

Kirk, K. I., Miyamoto, R. T., Ying, E. A., Perdew, A. E., & Zuganelis, H. (2000). Cochlear implantation in young children: Effects of age at implantation and communication mode. *Volta Review*, *102*(4), 127-144.

Krashen, S. (1989). We Acquire Vocabulary and Spelling by Reading: Additional Evidence for the Input Hypothesis. *The Modern Language Journal*, *73*(4), 440–464. https://doi.org/10.2307/326879

Kucker, S. C., McMurray, B., & Samuelson, L. K. (2015). Slowing Down Fast Mapping: Redefining the Dynamics of Word Learning. *Child Development Perspectives*, *9*(2), 74–78. https://doi.org/10.1111/cdep.12110

Kuhn, M. R., & Stahl, S. A. (1998). Teaching Children to Learn Word Meanings from Context: A Synthesis and Some Questions. *Journal of Literacy Research*, *30*(1), 119–138. https://doi.org/10.1080/10862969809547983

Kyle, F. E., & Harris, M. (2011). Longitudinal Patterns of Emerging Literacy in Beginning Deaf and Hearing Readers. *The Journal of Deaf Studies and Deaf Education*, *16*(3), 289–304. https://doi.org/10.1093/deafed/enq069

Lee, J. (2011). Size matters: Early vocabulary as a predictor of language and literacy competence. *Applied Psycholinguistics*, *32*(1), 69–92. https://doi.org/10.1017/S0142716410000299

Li, P., Zhao, X., & Mac Whinney, B. (2007). Dynamic Self-Organization and Early Lexical Development in Children. *Cognitive Science*, *31*(4), 581–612. https://doi.org/10.1080/15326900701399905

L.C. Ehri. (1978). Beginning reading from a psycholinguistic perspective: Amalgamation of word identities. In F. B. Murray (Ed.), *The recognition of words* (pp. 1–33).

Lucas, R., & Norbury, C. F. (2014). Orthography facilitates vocabulary learning for children with autism spectrum disorders (ASD). *Quarterly Journal of Experimental Psychology (2006)*, *67*(7), 1317–1334. https://doi.org/10.1080/17470218.2013.859714

Luckner, J. L., & Cooke, C. (2010). A summary of the vocabulary research with students who are deaf or hard of hearing. *American Annals of the Deaf*, *155*(1), 38–67.

Lund, E., & Douglas, W. M. (2016). Teaching Vocabulary to Preschool Children With Hearing Loss. *Exceptional Children*, *83*(1), 26–41. https://doi.org/10.1177/0014402916651848

Lund, E., & Schuele, C. M. (2014). Effects of a word-learning training on children with cochlear implants. *Journal of Deaf Studies and Deaf Education*, *19*(1), 68–84. https://doi.org/10.1093/deafed/ent036

Marchman, V. A. and Fernald, A. (2008), Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. Developmental Science, 11: F9–F16. doi:10.1111/j.1467-7687.2008.00671.x

Marschark 2004 ORGANIZATION AND USE OF THE MENTAL LEXICON.pdf. (n.d.). Retrieved from https://www.uv.es/infabra/Marschark%202004%20ORGANIZATION%20AND%20USE%20OF%20THE%20MENTAL%20LEXICON.pdf

Marschark, M., Convertino, C., McEvoy, C., & Masteller, A. (2004). Organization and Use of the Mental Lexicon by Deaf and Hearing Individuals. *American Annals of the Deaf*, *149*(1), 51–61. https://doi.org/10.1353/aad.2004.0013

Marschark, M., & Spencer, P. E. (2015). *The Oxford Handbook of Deaf Studies in Language*. Oxford University Press.

Marschark, M., & Spencer, P. E. (2016). *The Oxford Handbook of Deaf Studies in Language*. Oxford University Press.

Mary K. Fagan, David B. Pisoni; Hearing Experience and Receptive Vocabulary Development in Deaf Children With Cochlear Implants, *The Journal of Deaf Studies and Deaf Education*, Volume 15, Issue 2, 1 March 2010, Pages 149–161, https://doi.org/10.1093/deafed/enq001

Mather, E., & Plunkett, K. (2009.). Learning Words Over Time: The Role of Stimulus Repetition in Mutual Exclusivity. *Infancy. 14*(1), 60–76. https://doi.org/10.1080/15250000802569702

Marulis, L. M., & Neuman, S. B. (2010). The Effects of Vocabulary Intervention on Young Children's Word Learning: A Meta-Analysis. *Review of Educational Research*, *80*(3), 300–335. https://doi.org/10.3102/0034654310377087

McBride–Chang, C., Wagner, R., Muse, A., Chow, B., & Shu, H. (2005). The role of morphological awareness in children's vocabulary acquisition in English. *Applied Psycholinguistics, 26*(3), 415-435. doi:10.1017/S014271640505023X

McKague, M., Davis, C., Pratt, C., & Johnston, M. B. (2008). The role of feedback from phonology to orthography in orthographic learning: an extension of item-based accounts. *Journal of Research in Reading*, *31*(1), 55–76. https://doi.org/10.1111/j.1467-9817.2007.00361.x

McKeown, M. G., Beck, I. L., & Sandora, C. (2012). Direct and Rich Vocabulary Instruction Needs to Start Early. In E. J. Kame'enui & J. F. Baumann, (Eds.), *Vocabulary instruction: Research to practice* (2 ed.). (pp. 17-33). New York: Guilford Publications, Inc.

McLaughlin, S. (2006). *Introduction to language development* (2nd ed.). Clifton Park, NY: Thomson Delmar Learning.

McMurray, B., Horst, J. S., & Samuelson, L. K. (2012). Word learning emerges from the interaction of online referent selection and slow associative learning. *Psychological Review*, *119*(4), 831–877. https://doi.org/10.1037/a0029872

Mengoni, S. E., Nash, H., & Hulme, C. (2013). The benefit of orthographic support for oral vocabulary learning in children with Down syndrome*. *Journal of Child Language*, *40*(1), 221–243. https://doi.org/10.1017/S0305000912000396

Messier, J., & Wood, C. (2015). Facilitating Vocabulary Acquisition of Children With Cochlear Implants Using Electronic Storybooks. *The Journal of Deaf Studies and Deaf Education*, *20*(4), 356–373. https://doi.org/10.1093/deafed/env031

Merriman, W. E., Bowman, L. L., & MacWhinney, B. (1989). The Mutual Exclusivity Bias in Children's Word Learning. *Monographs of the Society for Research in Child Development*, *54*(3/4), i-129. https://doi.org/10.2307/1166130

Morra, S., & Camba, R. (2009). Vocabulary learning in primary school children: Working memory and long-term memory components. *Journal of Experimental Child Psychology*, *104*(2), 156–178. https://doi.org/10.1016/j.jecp.2009.03.007

Mueller, J. L., Friederici, A. D., & Männel, C. (2012). Auditory perception at the root of language learning. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(39), 15953–15958. http://doi.org/10.1073/pnas.1204319109

Nagy, W. E., Herman, P. A., & Anderson, R. C. (1985). Learning Words from Context. *Reading Research Quarterly*, *20*(2), 233–253. https://doi.org/10.2307/747758

Nagy, W., & Scott, J. (2014). Vocabulary Processes. In M. L. Kamil, *Handbook of Reading Research* (Vol. 3, pp. 269–284). Routledge.

Nicholas, J. G., & Geers, A. E. (2006). Effects of early auditory experience on the spoken language of deaf children at 3 years of age. *Ear and Hearing*, *27*(3), 286–298. https://doi.org/10.1097/01.aud.0000215973.76912.c6

Nittrouer, S., Caldwell-Tarr, A., Low, K. E., & Lowenstein, J. H. (2017). Verbal Working Memory in Children With Cochlear Implants. *Journal of Speech, Language, and Hearing Research*, *60*(11), 3342–3364. https://doi.org/10.1044/2017_JSLHR-H-16-0474

Oullette, G. P. (2006). What's Meaning Got to Do with It: The Role of Vocabulary in Word Reading and Reading Comprehension. *Journal of Educational Psychology*, *98*(3), 554–566. doi:10.1037/0022-0663.98.3.554

Kucker, S. C., McMurray, B., & Samuelson, L. K. (2015). Slowing Down Fast Mapping: Redefining the Dynamics of Word Learning. *Child Development Perspectives*, *9*(2), 74–78. https://doi.org/10.1111/cdep.12110

Park, J., Lombardino, L. J., & Ritter, M. (2013). Phonology Matters: A Comprehensive Investigation of Reading and Spelling Skills of School-Age Children With Mild to Moderate Sensorineural Hearing Loss. *American Annals of the Deaf*, *158*(1), 20–40. https://doi.org/10.1353/aad.2013.0013

Perfetti, C. (2007a). Reading Ability: Lexical Quality to Comprehension. *Scientific Studies of Reading*, *11*(4), 357–383. https://doi.org/10.1080/10888430701530730

Perfetti, C., & Hart, L. (2002). Lexical Quality Hypothesis. In L. T. Verhoeven, C. Elbro, & P. Reitsma, *Precursors of Functional Literacy*. John Benjamins Publishing

Pisoni, D. B., & Cleary, M. (2003). Measures of working memory span and verbal rehearsal speed in deaf children after cochlear implantation. *Ear and Hearing*, *24*(1 Suppl), 106S–20S. https://doi.org/10.1097/01.AUD.0000051692.05140.8E

Pittman, A. L., Lewis, D. E., Hoover, B. M., & Stelmachowicz, P. G. (2005). Rapid word-learning in normal-hearing and hearing-impaired children: effects of age, receptive vocabulary, and high-frequency amplification. *Ear and Hearing*, *26*(6), 619–629. 10.1097/01.aud.0000189921.34322.68

Plunkett, K., Sinha, C., Moller, M. F., & Standsby, O. (1992). Symbol Grounding or the Emergence of Symbols? Vocabulary Growth in Children and a Connectionist Net. *Connection Science*, *4*(3–4), 293–312. https://doi.org/10.1080/09540099208946620

Regier, T. (2003). Emergent constraints on word-learning: a computational perspective. *Trends in Cognitive Sciences*, *7*(6), 263–268. http://dx.doi.org/10.1016/S1364-6613(03)00108-6

Regier, T. (2005). The emergence of words: attentional learning in form and meaning. *Cognitive Science*, *29*(6), 819–865. https://doi.org/10.1207/s15516709cog0000_31

Ricketts, J., Bishop, D. V. M., & Nation, K. (2009). Orthographic facilitation in oral vocabulary acquisition. *The Quarterly Journal of Experimental Psychology*, *62*(10), 1948–1966. https://doi.org/10.1080/17470210802696104

Ricketts, J., Dockrell, J. E., Patel, N., Charman, T., & Lindsay, G. (2015). Do children with specific language impairment and autism spectrum disorders benefit from the presence of orthography when learning new spoken words? *Journal of Experimental Child Psychology*, *134*, 43–61. https://doi.org/10.1016/j.jecp.2015.01.015

Ricketts, J., Nation, K., & Bishop, D. V. M. (2007). Vocabulary Is Important for Some, but Not All Reading Skills. *Scientific Studies of Reading*, *11*(3), 235–257. https://doi.org/10.1080/10888430701344306

Romberg, A. R., & Saffran, J. R. (2010). Statistical learning and language acquisition. *Wiley Interdisciplinary Reviews. Cognitive Science*, *1*(6), 906–914. http://doi.org/10.1002/wcs.78

Rosenthal, J., & Ehri, L. C. (2008). The mnemonic value of orthography for vocabulary learning. *Journal of Educational Psychology*, *100*(1), 175–191. https://doi.org/10.1037/0022-0663.100.1.175

Sadoski, M., & Paivio, A. (2004). A dual coding theoretical model of reading. In Alvermann, D. E., Unrau, N. J., & Ruddell, R. B. (Eds.) *Theoretical models and processes of reading.* (1329-1362). *Retrieved from https://ebookcentral-proquest-com.simsrad.net.ocs.mq.edu.au*

Saffran, J. R. (2001). Words in a sea of sounds: the output of infant statistical learning. *Cognition*, *81*(2), 149–169. https://doi.org/10.1016/S0010-0277(01)00132-9

Saffran, J. R. (2002). Constraints on statistical language learning. *Journal of Memory and Language, 47*(1), 172-196. http://dx.doi.org/10.1006/jmla.2001.2839

Saffran, J. R. (2003). Statistical Language Learning: Mechanisms and Constraints. *Current Directions in Psychological Science*, *12*(4), 110–114. https://doi.org/10.1111/1467-8721.01243

Sanders, L. D., Stevens, C., Coch, D., & Neville, H. J. (2006). Selective auditory attention in 3- to 5-year-old children: an event-related potential study. *Neuropsychologia*, *44*(11), 2126–2138. https://doi.org/10.1016/j.neuropsychologia.2005.10.007

Sarchet T, Marschark M, Borgna G, Convertino C, Sapere P, Dirmyer R. Vocabulary Knowledge of Deaf and Hearing Postsecondary Students. *Journal of postsecondary education and disability*. 2014;27(2):161-178.

Seashore, R. H. (1948). The Importance of Vocabulary in Learning Language Skills. *Elementary English*, *25*(3), 137–160.

Schorr, E. A., Roth, F. P., & Fox, N. A. (2008). A Comparison of the Speech and Language Skills of Children With Cochlear Implants and Children With Normal Hearing. *Communication Disorders Quarterly*, *29*(4), 195–210. https://doi.org/10.1177/1525740108321217

Shibles, B. H. (1959). How Many Words Does a First-Grade Child Know? *Elementary English*, *36*(1), 42–47.

Singh, L., Steven Reznick, J., & Xuehua, L. (2012). Infant word segmentation and childhood vocabulary development: a longitudinal analysis. *Developmental Science*, *15*(4), 482-495. 10.1111/j.1467-7687.2012.01141.x

Siskind, J. M. (1996). A computational study of cross-situational techniques for learning word-to-meaning mappings. *Cognition*, *61*(1), 39–91. https://doi.org/10.1016/S0010-0277(96)00728-7

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., & Lewis, D. E. (2004). Novel-word learning in children with normal hearing and hearing loss. *Ear and Hearing*, *25*(1), 47–56. https://doi.org/10.1097/01.AUD.0000111258.98509.DE

Storkel, H. L., & Lee, S. Y. (2011). The independent effects of phonotactic probability and neighbourhood density on lexical acquisition by preschool children. *Language and Cognitive Processes*, *26*(2), 191-211. https://doi.org/10.1080/01690961003787609

Swingley, Daniel. "Fast mapping and slow mapping in children's word learning." *Language learning and Development* 6, no. 3 (2010): 179-183. https://doi.org/10.1080/15475441.2010.484412

Tincoff, R., & Jusczyk, P. W. (1999). Some Beginnings of Word Comprehension in 6-Month-Olds. *Psychological Science*, *10*(2), 172–175. https://doi.org/10.1111/1467-9280.00127

Tincoff, R., & Jusczyk, P. W. (1999). Some Beginnings of Word Comprehension in 6-Month-Olds. *Psychological Science*, *10*(2), 172–175. https://doi.org/10.1111/1467-9280.00127

Trehub, S. E. & Henderson, J. L. (1996). Temporal Resolution in Infancy and Subsequent Language Development. *J Speech Hear Res*, 39(6), 1315-1320. doi: 10.1044/jshr.3906.1315.

Walker, E. A., & McGregor, K. K. (2013). Word learning processes in children with cochlear implants. *Journal of Speech, Language, and Hearing Research: JSLHR*, *56*(2), 375–387. https://doi.org/10.1044/1092-4388(2012/11-0343)

Wang, H.-C., Castles, A., Nickels, L., & Nation, K. (2011). Context effects on orthographic learning of regular and irregular words. *Journal of Experimental Child Psychology*, *109*(1), 39–57. https://doi.org/10.1016/j.jecp.2010.11.005

Waxman, S. R., & Lidz, J. L. (2007). Early World Learning. In *Handbook of Child Psychology*. John Wiley & Sons, Inc. https://doi.org/10.1002/9780470147658.chpsy0207.

Werker, J. F., & Yeung, H. H. (2005). Infant speech perception bootstraps word learning. *Trends in cognitive sciences*, *9*(11), 519-527. https://doi.org/10.1016/j.tics.2005.09.003

Wiig, E. H., Secord, W., & Semel, E. M. (2004). *CELF preschool 2: clinical evaluation of language fundamentals preschool*. Pearson/PsychCorp.

Willstedt-Svensson, U., Löfqvist, A., Almqvist, B., & Sahlén, B. (2004). Is age at implant the only factor that counts? The influence of working memory on lexical and grammatical development in children with cochlear implants. *International Journal of Audiology*, *43*(9), 506–515.

Woodward, A. L., & Markman, E. M. (1998). Early word learning. In W. Damon (Ed.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (pp. 371-420). Hoboken, NJ: John Wiley.

Xu, F., & Tenenbaum, J. B. (2007). Word learning as Bayesian inference. *Psychological Review, 114*(2), 245-272. http://dx.doi.org/10.1037/0033-295X.114.2.245

Yu, C., & Ballard, D. H. (2007). A unified model of early word learning: Integrating statistical and social cues. *Neurocomputing*, *70*(13-15), 2149-2165. https://doi.org/10.1016/j.neucom.2006.01.034

Yu, C. (2008). A statistical associative account of vocabulary growth in early word learning. *Language learning and Development*, *4*(1), 32-62. https://doi.org/10.1080/15475440701739353

Appendix

Appendix A

Information on participants' hearing loss and device-use

Device	Hearing Loss	No. of participants	Participant IDs
Cochlear implants	Bilateral Profound	6	4, 6, 9, 11, 12, 14
	Bilateral Severe-Profound	1	8
	Bilateral sloping Mild-Severe	1	2
	Bilateral Moderate Hi Frequency	1	10
Cochlear Implant + Hearing Aid	Left: Moderate sloping (HA) Right: Moderate-Severe (CI)	1	13
Hearing Aids	Bilateral Mild-Moderate	1	1
	Left Mild-Moderate: Right Profound	1	3
	Bilateral Mild sloping to Profound	1	5
	Left Severe: Right Moderate-Severe	1	7

Appendix B

Detailed participant information.

Participant IDs	Age (years;months)			CELF - 4 [a]		PPVT [a]	CC-2 [b]		
	At time of testing	HA fitting	CI-implant	Recep-tive	Expre-ssive		Regular word reading	Irregular word reading	Non-word reading
1	12;0	0;3	-	64	61		37	23	31
2	9;5	-	4;2	88	89	103	37	22	37
3	9;5	3;2	-	57	65	79	27	17	12
4	11;7	-	1;8	81	82	93	38	22	32
5	8.9	4;5	-	58	49	63	38	18	33
6	9;7	-	0;8	82	80	83	30	20	16
7	9;7	0;3	-	77	68	76	38	29	35
8	11;3	-	2;4	52	51	50	11	6	6
9	10;5	-	0;7	77	95	90	30	19	30
10	9;7	-	5;3	98	100	118	38	22	33
11	9;4	-	2;3	72	65	75	31	18	21
12	8;7	-	0;8	75	70	86	35	20	30
13	9;1	2;3	4;2	74	57	82	33	27	28
14	7;11	-	3;7	54	52	80	15	10	10

Note: HA- Hearing Aid; CI- Cochlear implant; CELF - 4, The Clinical Evaluation of Language Fundamentals; PPVT-4, Peabody Picture Vocabulary Test ; CC2, Castles & Coltheart 2.
[a]Standard scores; [c]Raw scores (Total=40)

Appendix C

27 April 2017

Dear Professor Castles **Reference No:** 5201700105 **Title:** *Orthographic facilitation for word learning in children with hearing loss*

Thank you for submitting the above application for ethical and scientific review. Your application was considered by the Macquarie University Human Research Ethics Committee (HREC (Human Sciences & Humanities)).

I am pleased to advise that ethical and scientific approval has been granted for this project to be conducted by:

• Macquarie University This research meets the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007 – Updated May 2015) (the *National Statement*). **Standard Conditions of Approval:**

1. Continuing compliance with the requirements of the *National Statement,* which is available at the following website:

http://www.nhmrc.gov.au/book/national-statement-ethical-conduct-human-research

2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol.

3. All adverse events, including events which might affect the continued ethical and scientific acceptability of the project, must be reported to the HREC within 72 hours.

4. Proposed changes to the protocol and associated documents must be submitted to the Committee for approval before implementation.

It is the responsibility of the Chief investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Ethics Secretariat on 9850 4194 or by email ethics.secretariat@mq.edu.au

The HREC (Human Sciences and Humanities) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human _research_ethics

The HREC (Human Sciences and Humanities) wishes you every success in your research. Yours sincerely

Dr Karolyn White

Director, Research Ethics & Integrity, Chair, Human Research Ethics Committee (Human Sciences and Humanities)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.