PHONOLOGICAL REPRESENTATIONS, PHONOLOGICAL AWARENESS, AND PRINT DECODING ABILITY IN CHILDREN WITH MODERATE TO SEVERE SPEECH IMPAIRMENT

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The material presented in this thesis is the original work of the candidate except as acknowledged in the text, and has not been previously submitted, either in part or in whole, for a degree at this or any other University.

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Abstract

The development of reading competency is one of the most significant pedagogical achievements during the first few years of schooling. Although most children learn to read successfully when exposed to reading instruction, up to 18% of children experience significant reading difficulty (Shaywitz, 1998). As a group, young children with speech impairment are at risk of reading impairment, with approximately 50% of these children demonstrating poor acquisition of early reading skills (Nathan, Stackhouse, Goulandris, & Snowling, 2004; Larivee & Catts, 1999). A number of variables contribute to reading outcomes for children with speech impairment including co-occurring language impairment, the nature and severity of their speech impairment as well as social and cultural influences. An area of research that has received increasing attention is understanding how access to the underlying sound structure or *phonological representations* of spoken words stored in long-term memory account for reading difficulties observed in children (Elbro, 1996; Fowler, 1991). Researchers have hypothesised that children with speech impairment may be at increased risk of reading disability due to deficits at the level of phonological representations (Bird, Bishop, & Freeman, 1995).

Phonological representation deficits can manifest in poor performance on tasks that require children to think about the sound structure of words. Knowledge about the phonological components of words is commonly referred to as *phonological awareness*. Identifying and manipulating phonemes within words are examples of phonological awareness skills. Some children with speech impairment perform poorly on phonological awareness measures compared to children without speech difficulties (Bird et al., 1995; Carroll & Snowling, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003). As performance on phonological awareness tasks is a strong predictor of early reading ability (Hogan, Catts, & Little, 2005), there is an important need to determine if children with speech impairment who demonstrate poor phonological awareness, have deficits at the level of phonological representations. This thesis reports a series of studies that investigated the relationship between phonological representations, phonological awareness, and word decoding ability in children with moderate to severe speech impairment. A child with complex communication needs (CCN) who used Augmentative and Alternative Communication (AAC) was also examined to determine how the absence of effective articulation skills influences the development of phonological representations.

The study employed a longitudinal design to compare the performance of nine children (aged 3:09-5:03 at initial assessment) with moderate to severe speech impairment and 17 children with typical speech development on novel assessment measures designed to determine characteristics of children's phonological representations. The tasks required children to judge the accuracy of spoken multisyllable words and newly learned nonwords. The relationships between performance on these tasks and measures of speech, phonological awareness and early print decoding were also examined. Four assessment trials were implemented at six-monthly intervals over an 18-month period. The first assessment trial was administered approximately 6 to12 months before children commenced school. The fourth trial was administered after children had completed 6 to 12 months of formal education. The child with CCN completed three assessment trials over a period of 16 months.

Data analyses revealed that the children with speech impairment had significantly greater difficulty ($p<0.01$) judging mispronounced multisyllable words compared to their peers with typical speech development. As a group, children with speech impairment also demonstrated inferior performance on the judgment of mispronounced forms of newly learned nonwords ($p<0.05$). No group differences were observed on the judgment of correctly pronounced real and nonword stimuli.

Significant group differences on speech production and phoneme segmentation tasks were identified at each assessment trial. Moderate to high correlations (i.e., r = 0.40 to 0.70)

were also observed between performance on the phonological representation tasks and performance on phonological awareness and speech production measures at each trial across the study. Although no significant group differences were observed on the nonword decoding task, 4 of the 9 children with speech impairment could not decode any letters in nonwords (compared to only 1 child without speech impairment) at the final assessment trial when children were 6-years-old. Two children with speech impairment showed superior nonword decoding ability at trial 3 and 4.

The within-group variability observed on the nonword decoding task highlighted the heterogeneity of children with speech impairment. The performances of four children with speech impairment with differing types of speech error patterns were analysed to investigate the role of phonological representations in their speech and phonological awareness development. The child with delayed speech development and excellent phonological awareness at trial 1, demonstrated superior phonological awareness and word decoding skills at age 6 years, although his performance on phonological representation tasks was inconsistent across trials. In contrast, a child with delayed development and poor early phonological awareness demonstrated weak performance on phonological representation, phonological awareness, and decoding at each successive assessment trial. The child with a high percentage of inconsistent speech error patterns generally demonstrated poor performance on phonological representation, phonological awareness and decoding measures at each of the 4 assessment trials. The child with consistent and unusual speech error patterns showed increasingly stronger performance on the phonological representation tasks and average performance on phonological awareness but limited word decoding ability at age 6. The 11-year-old girl with CCN, whose speech attempts were limited and unintelligible, demonstrated below average performance on phonological representation tasks, suggesting that an absence of articulatory feedback may negatively influence the development of well-specified phonological representations.

This thesis provides evidence for the use of receptive tasks to identify differences in the phonological representations of children with and without speech impairment. The findings also provide support for the link between the representation of phonological information in long-term memory and children's speech production accuracy, phonological awareness and print decoding ability. The variable performance of some children with speech impairment and the child with cerebral palsy demonstrate the need to consider individual characteristics to develop an understanding of how children store and access speech sound information to assist their acquisition of early reading skills.

Publications arising from this thesis

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List of Acronyms and Abbreviations

AAC – Augmentative and alternative communication

CCN – Complex communication needs

CV – Consonant Vowel

DAPHO - Developmental Model of Adult Phonological Organisation

NAM – Neighbourhood activation model

NW learning – Nonword learning

PA Probes – Phonological awareness probes

PARSYN – Paradigmatic Syntagmatic model

PDP - Parallel-distributed-processing

PR judgment – Phonological representation judgment

SARAH - Syllable Acquisition, Representation, and Access Hypothesis

WRAPSA - Word Recognition and Phonetic Structure Acquisition

Chapter 1. Literature Review

1.1 Introduction

The ability to efficiently and accurately decode and comprehend written text is critical for participation in academic, professional and social contexts within a literate society. Most children acquire competency in reading during the primary school years with further refinements taking place through secondary and tertiary education. More advanced and specialised reading knowledge continues to develop as people are exposed to different personal, vocational and community environments. Despite reading instruction, however, up to 18% of children experience significant difficulties acquiring reading and spelling skills (Shaywitz, 1998). Longitudinal studies of young children with reading disability have reported poor word recognition skills continuing through to adolescence (Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Shaywitz et al., 1999) and adulthood (Bruck, 1990). Recent research investigating the causes of persistent reading disability has focused on children's phonological development. An important question arising from this research relates to understanding what relationship exists between phonological representations of spoken words stored in memory and the ability to decode printed words.

Reading development is inherently linked to the ability to process speech sound information (Stanovich, 1988, 2000). To access the meaning of printed words, children must possess knowledge about the relationship between printed letters and speech sounds. This knowledge is particularly important when attempting to read new or unfamiliar words in an alphabet-based written language such as English. Central to this decoding process is the translation of printed words into speech sounds. For example, to comprehend a known word (but unfamiliar in printed form), a child must convert letters into sounds and hold the sounds in short-term memory. A child then uses this incoming information to identify the word and access the word’s meaning. The child’s speech motor system is then activated after identification of the target word, in order to say the target word.

Young children decipher new or unfamiliar words using a variety of decoding strategies. McGuinness (1997) reported 3 strategies used by first grade children. Children were identified as 1) *phoneme decoders* (i.e., analysing words phoneme-by-phoneme); 2) *part-word decoders* (i.e., searching for and relying on small words or parts of words within larger words); and, 3) *whole-word guessers* (i.e., decoding the initial sound and using visual characteristics of the remainder of the word to guess the word). Children who employed a phoneme-by-phoneme approach to decode unfamiliar words demonstrated the best reading outcomes in third grade (McGuinness, 1997). To become effective at decoding printed words using a phoneme-by-phoneme approach, children must develop an ability to map the speech sounds associated with printed letters onto existing information about a word’s sound structure or phonological representation. The cognitive storage of speech sound information related to words is, therefore, critical to reading development.

Phonological representation deficit hypotheses for reading disabilities emphasise the importance of accessible and well-specified phonological representations to facilitate the development of reading (Elbro, 1996; Elbro, Borstrøm, & Petersen, 1998; Fowler, 1991; Metsala & Walley, 1998; Walley, 1993). These hypotheses specify that children with reading disability may experience difficulty accessing phonological representations that contain phoneme-level information (Fowler, 1991; Metsala & Walley, 1998), or possess phonological representations that are not well differentiated from other words with similar speech sound structures (Elbro et al., 1998). These hypotheses are supported by evidence of children’s poor performance on tasks requiring the identification and manipulation of phonemes within words. Success on these tasks is referred to as demonstration of phonological awareness (Goswami & Bryant, 1990).

Phonological awareness is the widely-used term that describes a person's explicit knowledge about the detail contained in underlying phonological representations of spoken words (i.e., syllables, onsets, rimes and phonemes). Phonological awareness abilities are considered sub-components of broader language-based skills such as meta-linguistic awareness and phonological processing skills (Gillon, 2004). Tasks that require identification or manipulation of components of a word's phonological representation are used to examine children's phonological awareness skills. Examples of syllable-level and phoneme-level awareness tasks include identifying the number of syllables in a word (*Syllable Segmentation*) (Dodd, Crosbie, McIntosh, Teitzel, & Ozanne, 2000) and removing the first sound of a word to identify a new word (*Phoneme Deletion*) (Stahl & Murray, 1994).

Children's level of phonological awareness and positive reading outcomes are closely related (Adams, 1990; Brady & Shankweiler, 1991; Wagner & Torgesen, 1987). Some children with speech impairment perform poorly on phonological awareness measures compared to children without speech difficulties, and are therefore at risk of developing reading disability (Bird, Bishop, & Freeman, 1995; Carroll & Snowling, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003). This creates an important need to determine if children with speech impairment, who demonstrate poor phonological awareness, have deficits at the level of phonological representations. Knowledge of the role of phonological representations in the development of speech production will enhance our understanding of why some children with speech impairment develop age-appropriate reading ability and other children struggle to develop reading skills. This knowledge is also important to determine optimal targets for intervention targeting speech and phonological awareness impairments. This thesis considers the role of phonological representations in the development of speech, phonological awareness and early word decoding ability in young children with and without speech impairment.

1.2 Phonological Representations

1.2.1 A definition of phonological representations

The term *phonological representation* describes the underlying sound structure of specific words stored in long-term memory (Locke, 1983). Conceptually, the information contained in a phonological representation includes a word's acoustic structure consisting of phonemic- and phonetic-level details. Young children's phonological representations may contain only general acoustic information with some notable phonetic characteristics that help to differentiate words from other words (Menyuk & Menn, 1979; Walley, 1993; Waterson, 1971). Additionally, a well-developed phonological representation is thought to contain auditory (e.g., speech sound) and visual (e.g., lip movement) information about a word that enable it to be perceived and then differentiated from other words (Stackhouse & Wells, 1997). During the perception of a word, the incoming auditory and visual information is matched with information contained in the phonological representation which then enables access to the word's semantic representation.

Phonological representations are closely linked and interact with other linguistic-based representations such as semantic and orthographic representations (Stackhouse & Wells, 1997). This interaction takes placed during speaking and reading tasks. For example, during a phonological awareness activity, a child may be shown a picture of a *cat* and asked to identify the first sound of the word. To identify to the correct phoneme (i.e., /k/), the child would need to access the phonological representation of the word. Depending upon the child's stage of reading development, access to the phonological representation may be obtained through either the semantic (i.e., based on visual input) representation or the orthographic representation – or a combination of both. Stackhouse and Wells's (1997) psycholinguistic model of speech processing asserts that speaking a word involves both the phonological and semantic representation components linking to a motor programme component that contains instructions on how to articulate a word. This model highlights the need for well-defined phonological representations that contain the appropriate level and clarity of speech sound information to enable children to pronounce words.

Phonological representations can be considered holistic or segmental. Holistic representations consist of words or groups of words that can only be produced or considered as single units. Segmental representations enable speakers to process phonological information at a syllable, onset-rime or phoneme-level (Fowler, 1991). Successful performance on phonological awareness tasks that require the manipulation of individual speech sounds relies on accessible and accurate phonological representations with segmental details (Elbro, 1996). For example, to identify the first phoneme in a word, access to a phonological representation that is at least partially segmental is necessary.

1.2.2 The nature of early phonological representations

The abstract nature of phonological representations presents challenges for researchers. This has lead to much debate in phonology and linguistics literature regarding the level of detail contained in young children's phonological representations. This debate has centred on determining whether or not infants and young children have access to phonetic and phonemic segments within phonological representations. Early models of phonological development such as the Natural (Stampe, 1969) and Generative models (Smith, 1973), proposed that young children possess adult-like phonological representations from around the time they begin to produce their first words. According to these models, errors observed in young children's speech may be attributable to innate constraints that impact on their speech production abilities (Smith, 1973; Stampe, 1969). Early speech perception studies, in which children have shown remarkable abilities to respond to phonemic-level changes in stimuli, have provided evidence to support this theory. Eimas, Siqueland, Jusczyk, and Vigorito (1971) used a high-amplitude sucking paradigm to demonstrate that 4-week-old infants were able to respond to changes in phonological stimuli. Infants were reported to significantly increase their sucking rate when presented with a new consonant-vowel (CV) stimulus. An important distinction, however, must be made between results from tasks utilising sensory-based responses, such as those demonstrated by infants during tasks based on the high-amplitude sucking paradigm, and findings from tasks requiring children to attend to stimuli, and then indicate a decision based on linguistic knowledge. Consequently, inferences about underlying phonological representations must be made cautiously, particularly when based on findings from speech perception studies involving young infants.

Infants' early phonological representations may be stored as whole units (Fowler, 1991; Metsala & Walley, 1998). As memory storage requirements increase with vocabulary growth, representations are gradually segmented into smaller units. This is evidenced by the simultaneous increase in children's vocabularies and their ability to reflect on sub-lexical components (Metsala, 1999). A shift from holistic to segmental phonological representations is also consistent with other areas of perceptual-cognitive development (Aslin & Smith, 1988).

Although abstract in nature, it is clear that phonological representations are essential to the development of spoken and written communication. An examination of theories and models of phonology illustrates the importance of phonological representations to the perception and production of speech.

1.3 Phonological Representations and Phonology Theory

The concept of phonological representations is a central component of theories of phonology. Early generative phonology theorists described the realisation of *surface* representations (i.e., speech sound productions) from *underlying* representations (i.e., information stored in long-term memory) through a process of *derivation* (Chomsky & Halle, 1968; Goldsmith, 1990). The derivation process involves the structured application of phonological output rules to underlying phonological representations to produce surface representations (i.e., spoken words). Macken (1980) also advocated the presence of perceptual encoding rules that influenced the development of underlying representations.

A dual-lexicon model of early phonological development suggested that infants possess two separate cognitive storage mechanisms for phonological representations (Spencer, 1986; Vihman, 1982). One mechanism contains representations based on perceptual stimuli and the other includes representations that form the basis for speech production. This model was based on the belief that infants were capable of perceiving a much greater level of phonetic information than they could produce (Matthei, 1989). To overcome the difficulty of advocating that children duplicate the storage of phonological, semantic, syntactic and morphological information about words, Matthei (1989) detailed an alternative dual-access model. In this model, children have one lexicon that includes storage of all information about a word, with two separate access pathways for perception and production purposes.

The more recent Optimality Theory (McCarthy & Prince, 1994) also refers to *input* (underlying) and *output* (surface) representations. According to Optimality Theory, output representations are generated from input representations through a process involving the production of many possible output options. These options are then evaluated through the application of a range of universal constraints. The option that is *optimal* or considered most *harmonic* within the constraints of the speaker's native language is then selected as the output representation (Barlow & Gierut, 1999).

1.4 Phonological Representations in Models of Adult Spoken Word Recognition

Phonological representations are of critical importance for models of adult spoken word recognition. These models have been based on how experienced listeners and speakers recognise spoken words. The main procedure required to correctly identify spoken words is the ability to discriminate between words with similar phonological characteristics (Luce & Pisoni, 1998; Marslen-Wilson, 1987; McQueen, Cutler, Briscoe, & Norris, 1995). The models postulate that the two main functions involved in this discrimination process are the *activation* of a set of possible target words and the *competition,* within this set of targets, for selection

(Jusczyk & Luce, 2002). Researchers have advocated both *top-down* and *bottom-up* approaches to these cognitive processes. A top-down approach specifies that information is initially processed at a high-level, and becomes more fine-grained during processing. For example, prior knowledge of a sentence or phrase may facilitate access to words and their individual speech sounds. In contrast, a bottom-up approach suggests that listeners initially use low-level information such as individual speech sounds to access higher level information associated with words and phrases. For example, knowledge that the initial sound of the word *dog* is /d/ will aid the search for the word by limiting possible target words to all words containing an initial /d/. Although models of spoken word recognition differ in their emphasis of each approach, phonological representations are integral components of both bottom-up and top-down processing. The models described below also diverge in the mechanisms involved in the discrimination process and the level of segmental detail contained in words stored in the lexicon.

1.4.1 Cohort model

The *Cohort* model (Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welsh, 1978) underpinned much of the early research into how words are represented at a cognitive level. The original model specified that when a listener hears a spoken word, the acoustic-phonetic information contained in the word is used to activate a set of words from memory (i.e., the Cohort) with similar initial sound segments (Marslen-Wilson & Welsh, 1978). For example, the word *brush* will generate a cohort of words including *bridge*, *broom*, *brown*, etc. A series of processes using bottom-up speech sound and top-down contextual information are then involved in matching the perceived word with the correct word from the cohort. The role of these processes is to eliminate words from the cohort until the target word can be uniquely identified. The central tenet of the model is that words are recognised as quickly as possible using the available elimination and identification mechanisms (Marslen-Wilson, 1987).

Warren and Marslen-Wilson (1988) argued that a finely tuned speech input system is able to eliminate words that differ from the target by single phonetic features.

Adults' ability to identify words based on limited speech input support the Cohort model (Walley, 1988). Results from tasks using a *gating paradigm* have shown that adults and children are able to identify spoken words after hearing the initial phoneme and part of the subsequent acoustic signal of words (Grosjean, 1980; Walley, Michela, & Wood, 1995). On the same task, children required longer acoustic signals to correctly identify the target word compared to adults (Metsala, 1997a). The gating paradigm illustrates how well-specified phonological representations support spoken word recognition processes. An inference from this model is that children and adults, who do not have access to well-specified phonological representations, may have difficulty recognising spoken words when a limited amount of phonetic information is available. Although the Cohort model implies that phonological representations contain some degree of segmental detail, the level of phonetic detail is not explicitly specified.

1.4.2 Trace model

The *Trace* model of speech perception (McClelland & Elman, 1986) provides a greater focus on the connections and interactions between different levels of phonological representations. Three distinct levels of processing units featured in the model equate with words, phonemes and distinctive features. These levels are connected, in a cognitive sense, and can be activated or suppressed during processing. The aim of the activation and suppression processes is to identify the target word as efficiently as possible using information from the three levels of processing. For example, when the word *dog* is perceived, the voiced feature is activated at the feature level. This, in turn, triggers voiced phonemes at the phoneme level. Words with voiced phonemes are also triggered through connections from the phoneme level. All words with voiceless phonemes and similar characteristics (e.g., *fog, hog*) will be suppressed to facilitate recognition of *dog*. The Trace model assumes the presence of accurate and detailed phonological representations. The model also provides functional simulations of word recognition and accounts for a wide range of speech recognition processes.

1.4.3 Shortlist model

Shortlist is a connectionist model that emphasises bottom-up phoneme-based processing and specifies two distinct stages of the word recognition process (Norris, 1994). The first stage includes the use of phoneme-level input to match with words in the lexicon. This process results in the creation of a *short list* of possible target words. The second stage involves the reduction of the list through a process of elimination, where words compete for recognition. The identification process is facilitated by the activation of inhibitory connections for words that do not share phonological features with the target word. The model also has supporting computation simulations that account for the isolation of words from continuous speech through the consideration of acoustic-phonetic contexts. The Shortlist model specifies that the processing of well-specified phonological representations takes place independently of higher-level influences such as semantic information. This contrasts with the close relationship between phonological and semantic representations specified in the *Neighbourhood Activation Model.*

1.4.4 Neighbourhood Activation model

The *Neighbourhood Activation Model* (NAM) (Luce & Pisoni, 1998) of spoken word recognition provides greater detail on the complexity of the storage of words in long-term memory. The model also advocates the consideration of contextual factors that influence word recognition. Luce and Pisoni (1998) developed the NAM model in an attempt to specify the organisation of words in the mental lexicon, according to words' speech sound information. This model is based on the assumption that similarities between words are one of the earliest factors involved in categorising phonological representations.

A hallmark of the NAM is the frequency-density effect (Luce, Pisoni, & Goldinger, 1990). The frequency – density effect specifies that the efficiency of spoken word recognition is influenced by the number of phonetically similar words in long-term memory, and the frequency with which these words are accessed. The model suggests that frequently used words are easier to recognise than words accessed less frequently (e.g., *car* versus *rake*). Similarly, words with few similar lexical neighbours (e.g., *leash*) are considered easier to perceive than words that share many similar features with other words. For example, *shack* can be considered as residing in a high-density lexical neighbourhood, sharing phonetic characteristics with words such as *sack, shock, hack, sack,* and *tack.* Luce and Pisoni (1998) reported that the frequency – density effect held true for the recognition of both single syllable real and nonwords presented to adults. Cluff and Luce (1990) also reported the effect for the recognition of compound words. Stimuli consisting of two low-frequency words from high-density neighbourhoods (e.g., *lifeboat* and *beehive*) were harder to perceive than stimuli created from two high-frequency words from low-density neighbourhoods (e.g., *catfish* and *deadline*).

Luce and Pisoni (1998) differentiate pure phonetic perception and spoken word recognition. Phonetic perception takes place without the factors that influence spoken word recognition such as noise, reverberation, and personal variables. In normal listeners, differences in memory, attention, and the ability to process auditory stimuli can lead to the loss or reduction of relevant phonetic information. Consideration of these and other factors such as variability in speaker characteristics and communication contexts are key features that differentiate the model from earlier models of spoken word recognition. The original NAM model, however, lacked specification of explicit segmental level detail (Luce, Goldinger, Auer, & Vitevitch, 2000). Knowledge of the segmental information available to children and adults during spoken word recognition is essential to developing our understanding of how this information influences speech perception and production. Specification of the segmental characteristics of phonological representations is also necessary to develop our understanding of the relationship between speech production and the development of phonological processing and reading.

1.4.5 PARSYN model

A recent derivative of NAM is the PARSYN (i.e., PARadigmatic – SYNtagmatic) model of word recognition (Luce et al., 2000). A central feature of the PARSYN model is its emphasis on the segmental components of phonological representations for spoken word recognition. PARSYN enhances the connectionist nature of NAM by including allophonic level details and processing capabilities to account for effects of linguistic phenomena such as probabilistic phonotactics during the recognition of spoken words. PARSYN specifies one word level unit, two allophonic level units (i.e., *input* and *pattern*) and multiple temporal positions involved in processing speech input. Similar to other connectionist models, PARSYN accounts for spoken word recognition through the triggering of multiple representations followed by a competitive procedure involving a series of inhibitory and facilitative processes across and between units of representation to identify the correct target word. The model accounts for the neighbourhood density effect through inhibitory processes at the word-level unit. Activation levels for allophonic-level units are set to deal with the probability of certain allophones appearing together. High-frequency allophones require less activation than low-frequency allophones, and allophones that are commonly combined together in words activate each other through facilitative links (Jusczyk & Luce, 2002).

1.4.6 Section summary

The Trace, Shortlist, and PARSYN models highlight the importance of segmental components of underlying phonological representations for the recognition of spoken words by mature listeners. According to these models, children require access to accurate phonological representations in order to demonstrate effective spoken word recognition skills.

The efficient identification of target words is dependent on connections and processes between levels and items of representation. The models, however, raise questions about the performance of children and adults who do not have adequate phonological representations. For example, the NAM specifies that spoken word recognition is affected by the frequency of use of lexical items, and the need to readily differentiate between similar phonological representations. As children with speech impairment are likely to use shorter sentences and phrases than children without speech impairment (Shriner, Holloway, & Daniloff, 1969), they may be at risk of spoken word recognition difficulties due to less exposure to vocabulary. Less frequent word use, however, may be a direct result of children with speech impairment having poor word recognition skills. Further investigation is needed to determine the relationship between speech impairment and phonological representations, and how this relationship manifests during spoken word recognition processes. The models described above also assume mature and effective cognitive functioning. There is a need, then, to consider other models that accommodate possible developmental differences in phonological representations.

1.5 Phonological Representations in Developmental Models of Spoken Word Recognition

Several models have been proposed to account for infants' development of early speech perception and production skills. These developmental models provide a theoretical context in which to consider the importance of phonological representations in the appearance of speech skills, as well as highlight skills that may be affected by deficits in phonological representations. Similar to models of well-developed spoken word recognition, these developmental models contrast the use of bottom-up (Mehler, Dupoux, & Segui, 1990) and top-down (Suomi, 1993) processing. Infants' perception of minimal sound contrasts supports the bottom-up approach to developing word recognition (Jusczyk, 1997). A bottom-up approach implies the early observation of phonemes and how they can be combined together, resulting in children learning how to use larger units such as syllables and words. In contrast, models that advocate top-down approaches are supported by observations that young children's attempts at speech target whole words or short phrases (Locke, 1983).

1.5.1 Syllable Acquisition, Representation, and Access Hypothesis (SARAH)

The *SARAH* model specified by Mehler et al. (1990), describes the relationships between the development of speech perception skills, spoken word recognition and the development of phonological representations. The model specifies three innate devices that assist infants to develop representations. These devices include a syllable filter, a phonetic decoder, and a word boundary detector. The syllable filter segments continuous speech into syllabic units and eliminates unique speaker variables. The phonetic decoder then segments the syllable outputs into phonetic components to enable the conversion of information into a code based on motor-speech movements required to produce the appropriate sounds. Word boundaries are then detected by analyses of the incoming speech signal, using speech sound information and syllable representations. This model is supported by reports that infants appear capable of integrating the use of prosodic cues with phonotactic and allophonic cues to identify words from a stream of speech, by around 12-months-of-age (Morgan & Saffran, 1995). For example, syllable stress patterns appear to be closely linked to infants' ability to detect word boundaries (Cutler & Norris, 1988).

During the first 12 months of life, infants' become more sensitive to syllables and word boundaries that enable access to their native language (Jusczyk, 1997). Mehler et al. (1990) proposed that this involves a compilation process that creates syllable and word-like templates to facilitate the extraction of information from continuous speech to develop representations of words. These templates may create representations that are quite different from adults, with single representations containing several words, as evidenced by young children's production of *phonological phrases* or *idioms* (Locke, 1983). For example, a young child may only use the word *see* in the phrase *see you later* (e.g., produced as /ijʌeidə/) for some months before using *see* in isolation or with other words. This example indicates that the word *see* was part of a larger phonological representation containing other words, and was unable to be considered at a more segmental level. Although the SARAH model introduces and describes important concepts such as phonetic decoders and syllable filters, the model does not comprehensively describe how phonological representations are thought to develop over time. By focussing on bottom-up approaches to the development of speech perception, the model neglects the goal of language acquisition, which is the ability to communicate with others (Jusczyk & Luce, 2002). The development of phonological representations, however, may be heavily influenced by top-down processes such as determining the meaning of utterances, phrases and words.

1.5.2 Developmental model of Adult Phonological Organisation (DAPHO)

Suomi (1993) specified the DAPHO model which utilises a top-down approach to account for the development of speech perception and production skills. The model specifies that each semantic representation in a child's lexicon has an auditory or perceptual representation that contains the acoustic features needed to identify the word in a variety of acoustic contexts. This does not imply phonetic-level detail. Lexical items in infants' long-term memory are unlikely to have many items that share similar acoustic characteristics. Infants may not, therefore, require detailed speech sound information to enable word recognition or attempts to produce spoken words (Jusczyk, 1992; Walley, 1993).

During speech perception, the auditory representations are used to identify possible word boundaries (Suomi, 1993). The incoming words are then compared with existing auditory representations to determine appropriate matches. If a match is made, the relevant semantic representation is accessed. Unfamiliar words initiate the specification of new auditory representations that are considered holistic with few relevant acoustic characteristics.

The new representations await addition and refinement from further acoustic-phonetic input provided during subsequent exposures to the same word. The model advocates that representations remain holistic without segmentation below word-level. In support of the model, Suomi (1993) reported Nittrouer and Studdert-Kennedy's (1987) findings that speech perception in children aged 3 to 5 years, appeared to be focused on identifying words as opposed to phoneme-sized segments.

In addition to a lack of empirical support, the DAPHO model contains several methodological weaknesses. The model does not specify how words are determined to be matches of existing words vs. new words. The proposal that isolating words from continuous speech relies on holistic representations does not account for the analysis of words with embedded words (e.g., the word *cap* in *capture, captain,* and *capital*) or compound words. By focusing on the process from a top-down perspective, the DAPHO model neglects valuable bottom-up processing information that may contribute to a more comprehensive description of the developmental process.

1.5.3 Word Recognition and Phonetic Structure Acquisition (WRAPSA)

To strengthen the limitations of models that focus on either bottom-up or top-down perspectives, Jusczyk (1993, 1997) developed a model that encompasses both approaches. The WRAPSA model advocates a combination of top-down and bottom-up processing to the development of children's phonological representations. WRAPSA specifies that phonological representations develop as children gradually acquire skills that enable them to analyse incoming speech stimuli. Two cognitive concepts central to this model are speech analysis templates or *schemes* and a *pattern extraction* mechanism. The speech schemes enable children to identify and process key speech sound features from acoustic input. As infants develop, their speech schemes become more attuned to sound contrasts and help listeners focus on the phonological features that are important in their native language. Rudimentary input representations are created by a pattern extraction mechanism that segments acoustic input into word-like forms. According to Jusczyk (1997), these early input representations contain prosodic information such as suprasegmental and syllable information (e.g., stress and duration). To identify target words, input representations are then compared with existing phonological representations. If the input representation is matched with an existing representation, the semantic information will be accessed. A failure to identify a close match results in input representations being reprocessed or stored as a new representation.

A characteristic of the WRAPSA model is the storage of individual phonological representations for separate experiences a young child has with the same word spoken by different speakers. This is in contrast to more proto-typical or global representations proposed by the DAPHO model. This feature is supported by evidence that infants under 12-months-of-age store speaker characteristics associated with words (Houston & Jusczyk, 2000). Infants aged between 7.5 and 10.5 months were familiarised with two words spoken by the same speaker, and then read passages containing the target words spoken by the original and different speakers. This task involved the presentation of visual stimuli (i.e., a flashing red light) to elicit a head turn response, followed by presentation of the auditory stimuli. Recognition was gauged by the length of time infants looked in the direction that stimuli were presented from. At 7.5 months, infants demonstrated recognition of the words spoken by the original speaker but not the different speakers, even after a 24-hour delay. By 10.5 months, infants were immediately able to generalise the words across speakers of the same gender. After a 24-hour delay period, however, infants were unable to generalise their recognition across speakers (Houston, Jusczyk, & Tager, 1998). This finding suggests that within the first year of life, infants' phonological representations contain speaker-specific information.

1.5.4 Section summary

The SARAH, DAPHO and WRAPSA models conceptualise key processes involved in developing word recognition skills. The models do not, however, accommodate a large body of research examining the importance of speech perception and speech production in word recognition. Developmental features such as the wide variation reported in children's acquisition of speech sounds, including children who have specific difficulties acquiring speech skills, are not accounted for under these models. Although the importance of underlying phonological representations to developing speech perception and production skills is specified, the models are not consistent in the proposed level of detail contained in young children's phonological representations. Several abstract concepts specified in the above models such as WRAPSA's pattern extraction mechanism (Jusczyk, 1997), also reduce the clinical application of the models. To extend the discussion of how phonological representations relate to early speech development and to explore the clinical relevance of phonological representations, the following sections provide a specific review of evidence from studies investigating the development of early speech perception and production skills in children.

1.6 Phonological Representations and Early Speech Perception and Production

1.6.1 Speech perception

Phonological representations are critical to the development of speech perception skills. Research during the past 35 years has provided a wealth of evidence for infants' ability to process speech, and to recognise spoken words (Aslin & Smith, 1988; Eimas et al., 1971; Jusczyk, 1997; Jusczyk & Aslin, 1995; Werker, 1991; Werker & Tees, 2005). DeCasper and Spence (1986) reported newborns responding to some supra-segmental information they were exposed to before birth. Expectant mothers read short stories twice each day for 6 weeks before birth. Using a high-amplitude sucking paradigm, the researchers found that within 3 days of birth, infants demonstrated a greater preference for passages read from the story exposed to in-utero compared to stories they were not exposed to. The recognition demonstrated by these infants may indicate some retention of general prosodic characteristics of phrases that facilitate innate responses on the task. This does not, however, indicate that detailed speech sound information resides in long-term memory. Newborns have also demonstrated an ability to discriminate between many phonetic contrasts (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987). Jusczyk (1992) reported that by age 4 months, infants were able to identify their mother's voice, detect the same syllables in different utterances and discriminate speech sound contrasts. Aslin and Smith (1988) suggested that young infants' perception of speech is over analytical in that they appear to use a great deal of information from the acoustic signal to identify speech characteristics. Jusczyk (1997), however, cautioned that it is not possible to determine the presence of well-formed phonological representations from performance on tasks involving innate sensory-based responses.

During the second 6 months of life, infants' speech perception appears to evolve from a primitive sensitivity to prosodic patterns, to comprehending some single words. This is supported by the emergence of early linguistic-based processing that requires some form of lexical-based phonological representation. Bortfeld, Morgan, Golinkoff, and Rathbun (2005) reported that 6-month-old infants demonstrated recognition of their own name and other familiar names during a head-turn procedure. Mandel, Jusczyk, and Pisoni (1995) found that by 6-months-of-age, infants demonstrated a preference for listening to their own name over other names with the same prosodic patterns. This finding suggests that these children's phonological representations include some level of speech sound information in addition to prosodic characteristics.

By age 8 months, infants' phonological representations may contain phonetic-level detail. Jusczyk and Aslin (1995) trained 7.5-month-old infants on a nonword (e.g., *tup*). Children had previously been exposed to a phonetically similar real word (e.g., *cup*). The infants were then presented with spoken phrases containing the target nonword or a real word distracter. During a head-turn paradigm task, infants indicated recognition of *tup,* but did not indicate familiarity with the word *cup*. This finding indicated that infants' were able to develop phonological representations that were fine-grained enough to discriminate between words based on a distinctive feature of the initial sound. Jusczyk and Hohne (1997) also reported that 8-month-old infants were capable of identifying familiar words from continuous speech and storing phonological information in long-term memory. Three stories were read daily to the infants for 10 days. After a two-week break, the infants listened for a longer period of time to words from the stories compared to similar words not included in the stories. A group of infants who were not exposed to the stories were also presented the word lists and showed no preference for either group of words. By around age 8-10 months, infants are able to recognise familiar single words (Benedict, 1979). Hallé and Boysson-Bardies (1994) also reported that 11-month-old French infants were beginning to recognise common words, and that by age 1, this ability was well established.

Studies of speech perception skills during the second and third year of life provide conflicting evidence for the level of phonetic detail contained in young children's representations. Several studies have reported children aged 1- to 4-years having difficulty discriminating minimal pairs consisting of familiar and unfamiliar words (Eilers & Oller, 1976; Gerken, Murphy, & Aslin, 1995; Kay-Raining Bird & Chapman, 1998). Stager and Werker (1997) reported that 14-month-old infants were unable to discriminate between a trained phonological representation linked to a novel shape and a minimal pair distracter (e.g., *dih* and *bih*). At the same age, infants were capable of performing the task using word pairs that were widely different (e.g., *neem* and *lif*) (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). By 17 months, however, children were able to discriminate between minimal pairs on this task (Werker, Fennell, Corcoran, & Stager, 2002). These studies employed a *switch* paradigm task. This involved the presentation of the target shape with the correct label or the distracter label. The length of time infants looked at each shape was compared between labels, with infants expected to look longer at the incorrect matching of a shape with a distracter label. Interestingly, presentation of the minimal pair stimuli to a group of 8-month-old infants produced a significant finding, indicating they were able to detect the phonetic differences better than older children. This was interpreted as older children activating newly acquired word learning skills resulting in decreased attention to fine-grained phonetic differences.

Several explanations have been proposed to account for this apparent change in young children's attention to phonetic-level information. Brown and Matthews (1997) suggested that phonetic and phonological changes involve two separate entities that undergo distinct developmental changes. Their proposal specified that infants' phonetic repertoire initially undergoes a reduction process as infants become familiar with the phonetic features relevant to their native language. This leads to the creation of phonological representations that contain the relevant acoustic contrasts for a child's native language (Brown & Matthews, 1997). Although the hypothesis implies that phonetic information is not necessarily contained within phonological representations. In contrast, Swingley (2003) and Werker et al. (2002) rejected the independence of phonetic and phonological development by arguing that if phonetic-level detail can be discriminated then it is accessible for phonological development. As an alternative, Stager and Werker (1997) proposed a *resource limitation* hypothesis to explain deterioration in infants' attention to phonetic-level detail. This hypothesis suggested that during the early stages of word learning, around the end of the first year and early in the second year of life, infants are allocating greater resources to detecting and forming words. This reduces their ability to attend to the phonetic-level detail contained in words. As a result of further cognitive development, children at 17- to 20-months are able to refocus on phonetic-level detail (Werker et al., 2002). These findings indicate that phonological representations and children's ability to attend to the information contained in representations undergo significant developmental changes in the first two years of life. Of particular importance to the current study is when and how young children develop phonological representations with segmental-level details. The evidence suggests that phoneme-level information may become available to some degree within the first year of life, with shifts in children's attention resources accounting for reduced task performance towards the end of the first year of life. This research is, however, subject to several criticisms.

A number of differences in experimental factors have resulted in conflicting findings on the level of phonetic detail available to infants. These include 1) different task methodologies (e.g., high amplitude sucking vs. head-turning vs. switch paradigms); 2) the familiarity of stimuli (e.g., familiar vs. unfamiliar vs. nonwords); and, 3) a child's level of phonological development (Swingley, 2003; Werker et al., 2002). Despite the inconsistent findings reported, there is evidence to suggest that by the end of their first year, infants possess and are able to develop phonological representations for some words. These appear to involve familiar words and contain information related to words. Some phonetic-level detail related to the initial sound segment may also be stored. This enables the representations to be accessed during word recognition procedures involving relatively passive subject participation (e.g., a head-turn paradigm task). Methodological challenges involved in examining young infants may preclude full specification of early phonological representations. Nevertheless, the level of detail contained in these early representations is sufficient to facilitate the appearance of infants' first spoken words.

1.6.2 Speech production

Additional information on the development of phonological representations can be gained from analyses of young children's speech production. Early phonological theories have used speech production data to support contrasting views on the level of detail contained in young children's phonological representations. Generative phonology theorists such as Smith (1973) argued that infants' early attempts at spoken words stem from adult-like phonological representations and that speech output is mediated by the application of a number of reduction rules or phonological processes. Consequently, young children's speech output is notably different from adults. This approach to analysing young children's spoken words fails to account for a number of early word productions that bear little resemblance of adult words or are fully adult-like without the application of phonological processes (Ferguson & Farwell, 1975). In contrast, Waterson (1971) argued that early speech errors were the result of incorrect perception of words. In her view, children were only capable of perceiving certain acoustic and prosodic features of words and only those characteristics that the child could physically produce were included in spoken words. Waterson (1971) provided evidence of this by illustrating young children's preference for certain speech sounds in their early words. Early research into speech production is characterised by several methodological shortcomings such as the predominance of observational case studies presenting anecdotal information on single subjects. This has been overcome more recently by well documented group studies and comparison between children growing up in different native language environments (Vihman, 1993; Vihman & de Boysson-Bardies, 1994).

A child's first spoken words emerge from the late babbling period, around 12-months-of-age (Vihman & Miller, 1988). First words rarely resemble adult-like productions of the target word and typically contain similar CV sound sequences observed during late babbling (Stoel-Gammon & Cooper, 1984; Vihman, 1991). These initial productions demonstrate an infants' ability to link a phonological representation with a semantic representation. For example, for a child to produce /bʌ/ for *bottle*, he/she may have associated the concept of a *bottle* with an underlying phonological representation that may or may not resemble /bʌ/. Infants' early word productions suggest that their phonological representations are somewhat primitive compared to adults' representations. Even when a child's spoken word may be a good match for the correct production of an adult-like word, it does not necessarily imply that a child has a phonological representation that is adult-like in its underlying structure (Locke, 1983). Leopold's (1947) widely documented production of an adult-like word *pretty* by his 10-month-old daughter Hildegard is widely reported as evidence for holistic or unanalysed early phonological representations. Initially, this production may be considered indicative of an adult-like phonological representation of the word *pretty*. Hildegard, however, subsequently reduced her production of *pretty* to /pɪti/ and /bɪti/ some months after her initial production. This apparent regression in accuracy indicated that her phonological system developed analytical components that included the application of more global phonological rules (Locke, 1983).

More recent speech production data has also provided evidence for the development and structure of phonological representations in young children (Echols & Newport, 1992). The recording and analysis of the spontaneous speech of young children from 17- to 23-months-of-age revealed that children were less likely to omit stressed and final syllables of multisyllable words compared to unstressed and initial or medial syllables. These findings suggest that young children's phonological representations contain syllable segment information by the middle to end of the second year of life. Walley (1993) argued that this syllable-level detail provides leverage for further segmentation of representations into more fine-grained components such as phonemes.

1.6.3 Studies of both speech perception and production

Consideration of perception and production skills in the same children is likely to yield the most clinically relevant information on the status and development of children's underlying phonological representations. Eilers and Oller (1976) observed that some speech production errors made by 2-year-olds were caused by perceptual deficits. Fourteen children were presented with a range of commonly mispronounced minimal pairs. The stimuli included words in both their correct and common error form (e.g., *car – gar*, *rabbit – wabbit*, *monkey – mucky*). During the task, children were introduced to, and played with objects representing the target word (e.g., a toy cow for /kau/) and a unique unfamiliar toy to represent the target word's minimal pair (e.g., a /pau/). A sweet was then placed in one of two containers, and the two toys (e.g., *cow* and *pow*) placed on top of the containers. The examiner then instructed the child with the statement "*it's under the [target word]"*. Each word in the minimal pair was targeted 4 times. Children's productions of the target words were transcribed to compare production with performance on the perception task. The results indicated that most children were adept at perceiving contrasts and some children were able to produce the contrast in speech (e.g., *car – gar*). Children were unable to perceive or produce some minimal pair contrasts (e.g., *rabbit – wabbit*, *fish – thish*). This finding suggests children do not have access to an accurate phonological representation for the perception or production of some words. So, although many speech sound contrasts are able to be discriminated by young children (e.g., voicing differences and /s/ versus /f/) (Locke, 1980; Strange & Broen, 1980; Velleman, 1988), other contrasts such as /r/ and /w/ remain difficult to perceptually discriminate and produce for children aged 3 years and older. Some fricative and glide sounds, therefore, may be stored incorrectly or unclearly in underlying phonological representations of older children. Interpretation of these findings should also take into account local dialectal differences and sound changes within a language. For example, most New Zealand children and up to 40% of young non-professional men and women substituted dental fricative sounds /θ/ and /ð/ with labio-dental fricatives /f/ and /v/ (Gordon & Maclagan, 1995). The substituted sounds, therefore, may not be present in the underlying phonological representations of many people.

Young children's articulation of words is also important in the development of phonological representations. In the study detailed above, Eilers and Oller (1976) reported that for two minimal pairs (e.g., *pig – tig, block - lock*) some children were able to produce the contrast on imitation, but were unable to identify the contrast on the perception task. Considering the imitative nature of the productions obtained by the Eilers and Oller (1976), it is possible that productions were not based on underlying phonological representations. Instead, the speech productions may have been processed through more direct speech processing pathways linking auditory input and speech output (Stackhouse & Wells, 1997). Straight (1980), however, argued that examples of spontaneous phonological idioms are evidence that children's production capabilities may influence speech perception. Vihman's (1982) model of phonology proposed a *relexification* route in phonological development. This indicates that children's speech productions provide specific auditory (and tactile) feedback that is used to add further specificity to children's developing phonological representations. This negative feedback is likely to hinder the development of phonological representations for children with unintelligible speech (Rvachew & Jamieson, 1989). The examination of children with CCN, who are unable to effectively articulate words, will provide insight into the specific role of articulation skills on the development of phonological representations.

1.6.4 Section summary

Evidence for the development of phonological representations is provided by the gradual appearance of speech perception and speech production skills in young children. By the third year of life, children are able to perceive and produce familiar words, many of which are close to adult-like productions. Particular speech sounds and sound combinations, however, may not be perceived or articulated correctly for some time (Velleman, 1988). In contrast to early phonological theory (e.g., Smith, 1973), recent perception and production studies indicate that young children's phonological representations undergo some form of developmental changes. These developmental changes enable 2- to 3-year-old children to produce phonologically complex words with adult-like articulation. Children with speech impairment, however, are unlikely to achieve adult-like speech accuracy. There is a need, therefore, to examine the development of phonological representations in young children with speech impairment.

1.7 Phonological Representations and Speech Impairment

A failure to demonstrate age-appropriate speech production is a common phenomenon, with up to 10% of preschool children presenting with speech impairment (Broomfield & Dodd, 2004; Gierut, 1998). Young children's speech impairments range in severity from a mild delay (e.g., consistently misarticulating one or two sounds) to severely unintelligible speech (e.g., less than 50% of consonants spoken correctly) (Shriberg & Kwiatkowski, 1982). Prevalence estimates of 6-year-olds with delayed or disordered speech development range between 3.8% of American children (Shriberg, Tomblin, & McSweeny, 1999) and 5% of New Zealand children (Gillon & Schwarz, 1999; Shriberg et al., 1999).

Significant variation is observed in children's progress in overcoming developmental speech errors. Shriberg, Kwiatkowski, and Gruber (1994) reported approximately 20% of American children referred to speech and language therapy services, at an average age of 4 years and 3 months, had achieved normal speech production within 12 months of referral. Shriberg, Kwiatkowski et al. (1994) followed 10 children identified with moderate to severe speech impairment during the preschool period and reported children as achieving *near normal* speech development after an average of 5 years post-referral. More rapid improvement in speech sound production from age 4 to 6 and from 7 to 8.5 years was also noted. As a group, children with moderate to severe speech impairment continued to have difficulty producing sounds such as /s/, /z/, /r/, and /l/ after age 9 (Shriberg, Gruber, & Kwiatkowski, 1994). These findings highlight the persistent nature of speech production errors for some children. Attempts to predict which children are most at risk of ongoing speech impairment can be facilitated by the sub-classification of speech impairment and consideration of factors that may influence speech development (Dodd, 2005).

Subtypes of speech impairment can be categorised in a number of ways. One method to conceptualise different sub-types is to consider the specific components involved within frameworks such as Stackhouse and Wells's (1997) model of speech processing. This model helps to contrast the underlying areas of difficulty for children with articulation vs. phonological disorders. For example, a child who produces a lateralised /s/, for every attempt at /s/, demonstrates an articulation disorder resulting from a difficulty executing the motor components of the speech process. This implies that isolated articulation impairments are not due to deficits at the level of underlying phonological representations. Considering the articulatory feedback (e.g., Vihman's (1982) relexification route) involved in speech development, however, isolated articulation impairment may well affect the development of underlying phonological representations. This is consistent with clinical evidence of many children presenting with a combination of both articulation and phonological impairments. In contrast, a child who substitutes all voiced fricative sounds with voiced stops may be demonstrating a higher level cognitive-linguistic deficit. This may include difficulties in storing and accessing phonological representations, production rules and phonological plans (Dodd, 2005).

A second method of differentiating children with speech impairment is the classification of *deviant* versus *delayed* development. Ingram (1989) defined deviant development as characterised by speech patterns not observed in typically developing children. For example, the substitution of all fricatives with the affricate sound /tʃ/. In contrast, the hallmark of delayed development is speech production similar to that of younger typically developing children. Dodd (2005) extended the notion of deviant development by specifying *deviant consistent* (i.e., the consistent use of deviant speech errors) and *deviant inconsistent* (i.e., the inconsistent use of deviant speech errors) categories. Considering the components of Stackhouse and Wells's (1997) model of speech processing, deviant inconsistent speech impairment is characterised by deficits in motor programming and planning components of speech production (Dodd, 2005; Dodd, Leahy, & Hambly, 1989). Information stored at the level of phonological representations should be relatively intact for these children, as phonological representations are located above the motor components on Stackhouse and Wells's (1997) model of speech processing. The poor phonological awareness demonstrated by children with deviant inconsistent speech impairment, compared to children with deviant consistent speech errors, provided evidence to support this sub-classification of children's speech impairment (Dodd et al., 1989). This indicated that children with deviant consistent speech impairment experienced deficits at the cognitive-linguistic level (i.e., phonological representation) of speech production (Dodd, 2005). The differential classification of children's speech error patterns, therefore, will assist the clarification of the role of phonological representations in speech impairment.

Absent or particularly severe articulation impairments are also likely to influence the development of phonological representations in children and adults with CCN (Bishop & Robson, 1989). Foley and Pollastek (1999) presented a comprehensive battery of reading-based lexical judgment tasks to adolescents and adults with CCN in an attempt to determine their ability to construct and access phonological representations in the absence of effective speech production skills. The tasks involved viewing pairs of phonologically-matched and non-matched real and nonwords. Participants were then required to indicate if stimuli were homophones. Results supported the hypothesis that articulatory skills were not prerequisite for developing phonological representations.

Smith (2001) suggested that adults with CCN may be more likely to experience problems in the specification of underlying phonological representations as indicated by poor performance on a lexical decision task. Smith (2001) compared spoken and written word judgment and phonological awareness skills in adults with CCN and reading-age-matched children with typical speech development. The spoken version of the task required participants to judge whether stimuli were real words. The stimuli presented included single and two-syllable words, with and without consonant clusters. Nonwords consisted of phonetically legal and illegal phoneme combinations. A total of 40 items were presented.

Results indicated that children without speech difficulties (aged 6- to 7-years) performed near ceiling on this task (i.e., range = 37 to 40). In comparison, scores from adults with CCN ranged from 24 to 40 items correct. The group difference narrowly failed to reach statistical significance. Further analysis of errors made by both groups, however, found that adults with CCN were more likely to accept nonwords as real words (i.e., false positive errors). In contrast, errors made by children without speech impairment were a combination of false positives and false negatives (i.e., incorrectly indicating a nonword instead of a real word) (Smith, 2001). Adults with CCN also took longer to indicate their judgements. These findings supported the hypothesis that adults with CCN may experience difficulty processing phonological information and accessing underlying phonological representations.

1.7.1 Speech impairment and reading development

Children with speech impairment are more likely to experience difficulty learning to read and spell compared to their peers without speech impairment (Bird & Bishop, 1992; Carroll & Snowling, 2004; Larivee & Catts, 1999). Nathan et al. (2004) reported 47% of children identified with isolated speech impairment at age 4, demonstrated poor reading and spelling ability at age 6:9 compared to children with typical speech development. This figure increased to 70% of children with co-existing speech and language impairments. Both the presence of co-existing language impairments (Bird et al., 1995; Bishop & Adams, 1990; Nathan et al., 2004) and the age at which speech impairments are resolved (Bird et al., 1995) are reported risk factors for reading disability in children with speech impairment. The *modified critical age hypothesis* (Nathan et al., 2004) suggests the risk of poor word decoding among children with speech impairment is reduced if speech errors are corrected and phoneme awareness skills emerging when children are first exposed to formal reading and spelling tuition. Findings from a longitudinal study that involved the presentation of speech perception and production, language, phonological awareness and early literacy tasks to 3 groups (n = 57) of children from age 4 to age 7 supported this hypothesis (Nathan et al., 2004). Children with persistent speech impairment at age 7 were more likely to perform poorly on reading and spelling measures compared to children who had resolved speech impairment and children in the control group.

Utilising a longitudinal design, Webster and Plante (1992, 1995) compared a group of children with speech impairment and age-matched children without speech impairment on measures of speech, phonological awareness, letter-name knowledge and sentence repetition. Children with speech impairment performed poorly on the sentence repetition (i.e., verbal memory) task. This task was also the best predictor of performance on the letter knowledge task (Webster & Plante, 1992, 1995; Webster, Plante, & Couvillion, 1997). In the same study, children's speech production was a strong predictor of performance on the letter knowledge task (Webster et al., 1997). The authors concluded that short-term verbal memory deficits appear central to difficulties children with speech impairment have on phonological awareness and letter knowledge tasks. This suggests a possible link between short-term memory and the development of phonological representations in long-term memory.

1.7.2 Speech impairment and spelling development

Some children with speech impairment also experience spelling difficulties. Lewis, Freebairn, and Taylor (2002) investigated two groups of children, one with speech impairment only and the other with speech and language impairment. Children with both speech and language impairment performed significantly below the level of children with isolated speech impairment, on speech, language, spelling, and reading measures. The children with isolated speech impairment also demonstrated poor spelling performance, reaching levels below those expected based on their IQ, reading and language scores. The authors hypothesised that weaknesses in their phonological representations of the target words resulted in spelling errors. These findings, however, should be interpreted with caution as no control group was examined and significant group differences were noted on age and socioeconomic measures (Lewis et al., 2002).

1.7.3 Section summary

Many preschool children with unintelligible speech and no physical or cognitive disability develop intelligible speech over a period of time (Shriberg, Gruber et al., 1994; Shriberg, Kwiatkowski et al., 1994). Phonological representations appear to be of central importance to the development of effective speech perception and production skills. It is not yet clear, however, whether improvements in speech intelligibility are influenced by or in turn facilitate changes in underlying phonological representations. Increasing our understanding of the relationships between speech impairment, underlying phonological representations, and cognitive processes involved in processing speech sound information will assist the identification of children at risk of persistent reading and spelling difficulties. This is important considering the difficulties many young children with speech impairment experience when learning to read (Larivee & Catts, 1999; Nathan et al., 2004).

1.8 Phonological Representations and Reading Development

Accomplished reading involves the ability to recognise written words (Gough & Tunmer, 1986; Stanovich, 2000). The development of visual word recognition is dependent on the processing of phonological information associated with printed words (Adams, 1990; Adams, Treiman, & Pressley, 1997; Share, Jorm, MacLean, & Matthew, 1984; Stanovich, 2000; Torgesen, Wagner, & Rashotte, 1994; Wagner & Torgesen, 1987). This specifically involves translating a written or orthographic representation into a corresponding phonological representation (Adams, 1990). For skilled readers, the translation from printed words to phonological and semantic representations occurs almost instantaneously without conscious intervention. Although there are a variety of cognitive skills associated with reading development, the significant variation in reading comprehension is accounted for by word recognition ability (Stanovich, 1985). The current discussion is therefore limited to word recognition and related processes. Over the past 30 years, a number of theories have been proposed that detail the processes involved in visual word recognition. These theories each state the importance of the storage and processing of phonological information associated with printed words and provide frameworks within which to consider the relationship between phonological representations and reading acquisition. The two most dominant generic models, *dual-route* and *connectionist* are discussed.

1.8.1 Dual-Route models

To become an effective reader, children must learn to decode printed words to access their meaning (Adams, 1990; Adams et al., 1997). Consistent with the phonological processing route of dual-route word recognition theories, the decoding process involves matching a printed word with an underlying phonological representation in order to access to the word's meaning or semantic representation (Ehri, 1992). For example, when children who are learning to read see an unfamiliar printed word (e.g., *milk*), they must be able to convert the printed symbols of the word into speech sounds to enable a match with their semantic conceptualisation of the word (e.g., *a white drink in plastic bottle found in the fridge*). The phonological processing route is not necessarily the only route to word recognition, with proponents of the visual route arguing that many irregularities in pronouncing English words (e.g., *couple* vs. *coupon*) require readers to bypass phonological representations and map orthographic representations directly onto semantic representations (Coltheart, 1978).

Dual route models (Coltheart, 1978; Coltheart, Curtis, Atkins, & Haller, 1993; Marshall & Newcombe, 1973) specify that the meaning of printed words can be accessed via two separate routes. The *phonological* route is consistent with an early view of reading that involved the conversion of written symbols into speech sounds to access the meaning associated with words (Gough, 1970). Observing a child attempting to read a word by producing one-sound-at-a-time is an example of application of the phonological route (Gillon, 2004). Access to words via the phonological route requires sub-skills such as letter-sound knowledge and phonological awareness skills such as phoneme segmentation and blending. The phonological route also requires readers to match incoming speech sound information from the grapheme-sound translation, with phonological representations in long-term memory. The model proposes that once words are learned via the phonological route, meaning can be accessed more directly through the *visual* route. The visual route is congruent with studies that indicate skilled readers can extract meaning from printed words by directly mapping orthographic representations onto semantic information, without reference to phonological representations (Besner, 1987). The exclusion of phonological processing from the visual route, however, has attracted widespread criticism (e.g., Ehri, 1992; Seidenberg, 1985). This criticism led to the development of several models that have addressed this shortcoming.

Modified dual-route models of word recognition have placed a greater emphasis on the role of underlying phonological representations during visual route processing of word recognition. Ehri (1992) specified that during the recognition of familiar and unfamiliar words, phonological representations mediate between a reader's knowledge of a word's orthographic and semantic representations. Under this model, a reader's grapheme-sound knowledge activates links between a word's orthographic and phonological representations which in turn enables access to the word's underlying meaning. This modified model proposed an intermediary step between phonologically-based and visually-based word recognition, with phonological representations playing an important role in the word recognition abilities of experienced readers.

1.8.2 Connectionist models

Phonological representations are central components of connectionist models of visual word recognition (Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Rumelhart & McClelland, 1986; Seidenberg, 1985; Seidenberg & McClelland, 1989). In contrast to dual-route theories, connectionist models advocate a *single procedure* that can account for word recognition. The parallel-distributed-processing (PDP) connectionist model (Seidenberg & McClelland, 1989) utilises a computer-based model that attempts to explain reading development phenomena by replicating the networks and processes involved in word recognition. The relative strength or influence of components can be manipulated to determine the effect on other components and development of skills over time (Harm & Seidenberg, 1999).

Connectionist models of visual word recognition share characteristics with spoken word recognition models. These include the use of facilitative and inhibitory mechanisms between phonological, orthographical, and semantic components to correctly identify the target word. The role of gradual learning is also a central tenet of connectionist modelling. An example of connectionist-based visual word recognition begins with the activation of the system with a printed word (e.g., *telephone*). In an immature system, this will possibly activate a range of target phonological representations that share similar orthographic characteristics (e.g., all words starting with the letter *t*). Facilitative and inhibitory connections and processes enable comparison of stimuli with existing orthographical, phonological, and semantic knowledge to identify the target word. The target word may or may not be correctly identified. This experience will enhance the systems ability to process the same stimulus in the future. The ongoing learning that takes place in the system helps develop robust connections between system components, leading to efficient word recognition. Seidenberg and McClelland's (1989) model and its' outgrowths demonstrate that knowledge of a word's phonological structure is important for reading both real and nonwords, including words that cannot be translated by applying a consistent letter-sound relationship (e.g., the variable New Zealand English pronunciation of the letter *y* in *syrup* and *synchronise*).

Connectionist modelling has also illustrated the role of phonological representations in reading development and the effects of disordered phonological components on several aspects of reading development (Harm & Seidenberg, 1999). After manipulation of the phonological component to replicate a phonological awareness impairment, the system demonstrated an impaired ability to transfer learned skills to unfamiliar words and reduced nonword reading accuracy.

The PDP model has been subject to in-depth criticism (Pinker & Prince, 1988). Coltheart et al. (1993) argued that the PDP model is unable to account for a wide range of behavioural characteristics observed in skilled and disabled readers. For example, the model's nonword reading performance was substantially below that of skilled adult-readers. Nevertheless, connectionist models provide a valuable contribution to the field by quantifying a range of abstract concepts and enabling real-time observation of reading development processes as well as possible implications of impaired development.

1.8.3 Section summary

Both dual-route and connectionist models of visual word recognition emphasize the central importance of phonological representations to reading development. The results reported by Harm and Seidenberg (1999) provide supporting, albeit artificial, evidence for effective readers to be able to reflect on phonological information contained in long-term memory. The models also imply that adults and children with deficits at the level of phonological representations are more likely to have difficulty developing efficient word recognition skills.

1.9 Phonological Representations and Dyslexia

Deficits in an individual's phonological development are central to developmental reading disabilities (Catts & Kamhi, 2005). The current definition of the term *dyslexia* proposed by Lyon, Shaywitz, and Shaywitz (2003) and advocated by the International Dyslexia Association emphasises the role of phonological processing deficits in reading difficulties experienced by children and adults. Lyon et al.'s (2003) definition states –

> It (*Dyslexia*) is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically

result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. (p. 2).

This definition contrasts with previous definitions of dyslexia that required the application of exclusionary criteria such as speech and language disorders, sensory and physical impairment, and environmental deprivation (Muter & Snowling, 2003). The reading and spelling errors observed in children with dyslexia appear to continue throughout their educational careers and later adult life (Bruck, 1990). A range of other factors such as neurological, visual, memory and language processes are often implicated in poor reading development. Recent research has also indicated many cases of dyslexia may have a genetic basis (Raskind et al., 2005).

The main difficulty for many children who experience reading failure is converting printed words into phonological codes (Liberman & Shankweiler, 1985; Share, 1995; Snowling, 1995). Frith (1980) and Torgesen (1985) first proposed that children with specific reading disabilities have underlying phonological deficits. Catts (1986) described these deficits as difficulty creating and accessing phonological representations and poor awareness of speech sound information. This is highlighted by difficulty children and adults with dyslexia display when attempting to read nonwords (Elbro, Nielsen, & Petersen, 1994; Ijzendoorn & Bus, 1994; Rack, Snowling, & Olson, 1992). The ability to access the segmental (e.g., phoneme) components of phonological representations is thought to underlie many of these word recognition difficulties (Elbro, 1996; Elbro et al., 1998; Fowler, 1991; Goswami, 2002; Liberman & Shankweiler, 1985; Metsala, 1997b).

The heterogeneity of children with dyslexia has resulted in a number of attempts to describe sub-groups of children and adults with poor reading ability. Catts, Hogan, and Fey (2003) described gross sub-groups based on auditory comprehension and visual word recognition abilities. Morris et al. (1998) provided finer sub-classifications by measuring children's performance on a range of visual, memory, speech, vocabulary and phonological awareness tasks. Based on clusters of strengths and weaknesses, 6 sub-types were proposed. All children with reading impairment performed poorly in at least one measure of phonological awareness (Morris et al., 1998). An additional sub-grouping model has proposed children with dyslexia demonstrate deficits in processing phonological information and/ or recognition and recall skills that facilitate rapid automatic naming (Wolf & Bowers, 1999; Wolf et al., 2002). Both of these skill-sets require access to underlying phonological representations in long-term memory.

Swan and Goswami (1997) hypothesised that children with dyslexia experience delayed development of their underlying phonological representations. Instead of progressing from holistic to segmental representations as described by Fowler (1991) and Walley (1993), their phonological representations may remain static at the onset-rime or syllable level, thus preventing access to phoneme-level information. Segmental representations, however, may develop for high-use words or words with regular grapheme-phoneme correspondence. To test this hypothesis, Swan and Goswami (1997) presented phonological awareness tasks to children aged 10 to 12 years with and without dyslexia. Children were first asked to name a series of pictures. Children's speech production was noted as either correct or incorrect for each word. These words were then used during four tasks examining syllable, onset-rime and phoneme-level awareness. Children with dyslexia performed consistently below chronological age-matched controls on the phonological awareness measures for all words presented (i.e., those pronounced correctly and incorrectly). An analysis of task performance on only those words pronounced correctly revealed that children with dyslexia performed at the same level as controls on the syllable and onset-rime awareness tasks. These children, however, continued to demonstrate significantly inferior performance on phoneme-level tasks using words pronounced correctly (Swan & Goswami, 1997). Articulation difficulty could not account for their inability to access phoneme-level details. The findings suggested that children with dyslexia have poor awareness of the phonological structure of words at the phoneme-level due to deficits in the storage of phonological representations. The results also supported their hypothesis that children with dyslexia experience a delay or halt in their development of representations containing phoneme-level detail.

The speech production difficulties identified in children with dyslexia by Swan and Goswami (1997) and others (e.g., Carroll & Snowling, 2004; Catts, 1986; Elbro et al., 1998) indicate the possibility of common underlying deficits in children with speech impairment and children with developmental dyslexia. Both groups of children may have difficulty accessing fully specified phonological representations for spoken words. These findings highlight the need for assessment measures that tap children's underlying phonological representations in addition to the accurate description of children's speech production and phonological awareness skills.

1.10 Phonological Representations and Phonological Awareness

Phonological awareness is critically important to early reading development (Adams, 1990; Gillon, 2004; Liberman, 1971, 1973; Whitehurst & Lonigan, 1998). For example, children who successfully perform phoneme segmentation and blending tasks are more likely to develop effective reading performance compared to children who have difficulty on such tasks (Juel, Griffith, & Gough, 1986; Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994). The ability to identify or manipulate phonemes in words between ages 4 and 7 is a powerful predictor of later reading and spelling performance (Bradley & Bryant, 1983; Lundberg, Olofsson, & Wall, 1980; Share et al., 1984). For example, Bradley and Bryant (1983) reported 4- and 5-year-old's scores on an initial phoneme identity task were predictive of scores on reading and spelling measures taken 3 years later.

Phonological awareness intervention facilitates the development of reading and spelling skills in young children (Ball & Blachman, 1991; Brady, Fowler, Stone, & Winbury, 1994; Bus & van Ijzendoorn, 1999; Byrne & Fielding-Barnsley, 1995; Byrne & Fielding-

Barnsley, 1993; Ehri et al., 2001; Gillon, 2000, 2002; Torgesen, Morgan, & Davis, 1992; Treiman & Baron, 1983; Treiman, Sotak, & Bowman, 2001; Wise, Ring, & Olson, 1999). Bradley and Bryant (1983) examined the nature of the relationship between phonological awareness and early reading and spelling abilities using a longitudinal study design involving explicit phonological awareness intervention (Bradley & Bryant, 1983). Children who received phoneme identity and letter-sound knowledge intervention over a 2-year period recorded significantly better spelling and reading outcomes compared to control children who did not receive any phonological awareness training. A group of children who received phoneme identity training only, demonstrated reading performance at the same level as children who received additional letter-sound training. These early findings and subsequent intervention studies are supportive of a causal link between early phonological awareness and later reading and spelling ability (Bradley & Bryant, 1983; Bus & van Ijzendoorn, 1999; Ehri et al., 2001).

The demonstration of phonological awareness implies that children have access to accurate and detailed phonological representations. For example, to successfully complete a phoneme segmentation task for the word *frog*, children must have access to a phonological representation that enables the identification and articulation of individual phonemes (i.e., /f/, /r/, /ɒ/, /g/). A child who has access to this phoneme-level information together with letter-sound knowledge should therefore be capable of decoding the printed word *frog* (i.e., assuming the child is unfamiliar with the printed word). A child, however, who is unable to access the individual phonemes within their phonological representation of the word *frog*, is unlikely to accurately segment or decode the printed word. This example illustrates the relationship between phonological awareness and reading development, as well as the role of phonological representations containing phoneme-level detail. The importance of good quality and easily accessible phonological representations to the development of phonological awareness is yet to be clearly specified. This ensures a need to explicitly examine the relationship between phonological awareness and phonological representations, particularly in populations known to be at risk of reading disability.

1.10.1 Development of phonological awareness

The expansion of phonological awareness skills are thought to stem from developmental changes in underlying phonological representations (Fowler, 1991; Walley, 1993; Elbro, 1996). Consequently, difficulties some children experience in developing phonological awareness and subsequent word recognition skills may be attributed to phonological representation deficits (Elbro et al., 1998; Fowler, 1991).

Phonological awareness appears to emerge in a general developmental pattern (Liberman, Shankweiler, Fischer, & Carter, 1974; Lonigan, Burgess, Anthony, & Barker, 1998; Treiman & Zukowsky, 1991). This involves the awareness of larger components of words (e.g., syllables) appearing before awareness of smaller components (e.g., phonemes). Although broad development trends have been reported, group studies have highlighted the wide variability in skill levels among 2- and 3-year-old children. An ability to detect a word that does not rhyme with two other rhyming words has been identified in some 2- (Lonigan et al., 1998) and 3-year-old children (MacLean, Bryant, & Bradley, 1987). Chaney (1992) reported that some 3-year-old children were capable of segmenting strings of words into single words, performing basic phoneme blending tasks and making rhyme judgments. Consistent performance across children, however, is not observed until after age 4 (Gillon, 2004). Dodd and Gillon (2001) reported that 4-year-old children were able to segment syllables. Successful performance on phoneme-level tasks has been reported to appear around age 5 among children from middle-class families, but not children from families with low-incomes (Lonigan et al., 1998). Although most children appear to follow the large-to-small development of awareness, some older children with reading disability have been reported as performing better on phoneme-level tasks than rime-level tasks (Duncan & Johnston, 1999).

The relative importance of the different levels of awareness to reading development is controversial. Specifically, debate has focussed on whether awareness of rime units or phoneme units exerts more influence on reading development. Bryant and colleagues (Bradley & Bryant, 1983, 1985; Bryant, MacLean, Bradley, & Crossland, 1990; Goswami & Bryant, 1990) hypothesised that pre-reading onset-rime awareness, provides the basis for two paths to reading development. First, by directly influencing children's reading development (e.g., a child who knows the rime unit of *ight* may use this knowledge to read words such as *fight, light, sight* etc) (Bryant, 2002). Second, by providing knowledge necessary to develop phoneme awareness that in turn directly influences reading development. Hulme et al., (2002) refuted this hypothesis after comparing onset-rime and phoneme awareness among good and poor readers and reporting phoneme awareness skills as a more accurate measure of future reading ability (Hulme et al., 2002; Muter, Hulme, Snowling, & Taylor, 1997). In return, Bryant (2002) criticised Hulme et al.'s (2002) interpretation of findings, based on the lack of IQ measure and the regular feedback provided to children during task presentation. This could have resulted in task learning influencing performance. In contrast, Anthony and Lonigan (2004) reanalysed data from several large scale studies and concluded that sensitivity to rime and phoneme units are best considered as components of a single underlying skill.

This debate has highlighted the multidimensional nature of phonological awareness. The timing or critical level of access to phonological detail that provides optimal long-term reading outcomes, awaits investigation. Perhaps, as Anthony and Lonigan (2004) alluded to, an early ability to access any component below the level of the syllable may be the important driver for later reading success. The ability to reflect on segmental components of words, together with additional developmental variables, may be sufficient for young children to develop good phonological awareness and reading outcomes.

Factors that underpin the development of phonological awareness skills include exposure to literacy learning opportunities, alphabet knowledge, meta-cognitive development and characteristics of underlying phonological representations. Levels of awareness such as syllable, onset and rime awareness may evolve out of speech development and exposure to language learning contexts such as nursery rhymes (Bryant, Bradley, MacLean, & Crossland, 1989) with minimal input from reading (Cheung, Chen, Lai, Wong, & Hills, 2001). Perfetti, Beck, Ball, and Hughes (1987) first reported the reciprocal relationship between phonological awareness and reading tuition. Some prerequisite level of awareness of words' components appears to facilitate maximum benefit from reading instruction. The process of learning to read then appears to enhance children's awareness of these components. Gillon (2004) suggested that reading lessons involving spelling-based instruction may assist children develop their phoneme-level awareness skills. Knowledge of letter names and that graphemes represent individual speech sounds also appear to share mutually beneficial relationships with phonological awareness and reading development (Burgess & Lonigan, 1998; Stahl & Murray, 1994; Wagner et al., 1994). Burgess and Lonigan (1998) reported that the level of letter-name knowledge directly influenced phoneme awareness development and a combination of phonological awareness task scores predicted development of letter knowledge among 4- and 5-year-old children. To transfer letter-name knowledge to early reading tasks, however, children first require knowledge of letter-sound correspondences and the development of meta-cognitive skills that enable them to blend individual sounds together to form words (Adams, 1990; Vernon, 1971).

Performance on phonological awareness tasks is the manifestation of meta-cognitive or meta-linguistic skills. Reflecting on the structure and components of speech requires the suspension or interruption of normal thought processes followed by a shift in attention to different attributes of stimuli (Fowler, 1991). Young children are typically unable to do this until they reach Piaget's stage of concrete operations around age 5 to 7 years. In attempting to explain the lack of phonological awareness in preschool children, early research focused on the meta-cognitive skills required to perform tasks (Liberman, 1973). This focus was consistent with the prevalent phonological theory at the time, in that preschooler's phonological representations were adult-like with segmental level details available (e.g., (Chomsky & Halle, 1968; Smith, 1973). Evidence to support this meta-cognitive model was provided by (Tunmer, 1988) who reported that children who had difficulty with non-linguistic meta-cognitive tasks during preschool were more likely to struggle with reading development during the first year of school. The difficulty with a strictly meta-cognitive account of phonological awareness development is that many children and adults with typical general intelligence, who demonstrate normal performance on visual meta-cognitive tasks, have reading disabilities and are unable to perform similar phoneme-based tasks (Fowler, 1991; Mann, Tobin, & Wilson, 1987).

1.11 Phonological Representation Deficit Hypotheses for Phonological Awareness and Reading Disability

Structural changes to the storage of phonological representations may facilitate early phonological awareness skills (Fowler, 1991; Walley, 1993; Metsala & Walley, 1998). Qualitative differences in underlying representations are thought to be central to reading and spelling difficulties experienced by children (Elbro, 1996; Elbro et al., 1998). This research has focused on children and adults with typical development and children who are either at risk of, or have a history of reading difficulties. These hypotheses provide insights into conceptual aspects of underlying phonological representations that may be critical to support the emergence of phonological awareness and reading.

1.11.1 Segmentation and lexical restructuring hypotheses

Two similar hypotheses focused on the development of young children's phonological representations, propose that words are initially holistic or stored as complete units without specific phoneme-level details. Both the *segmentation* (Fowler, 1991) and the *lexical restructuring* (Metsala & Walley, 1998; Walley, 1993) hypotheses propose that from around

12-months-of-age (Fowler, 1991) or from around the time children acquire 50 spoken words (Walley, 1993), the structure of children's phonological representations begin to change. Both hypotheses suggest that expanding vocabulary requirements force the child's phonological storage system to find a more efficient structure. These structural changes involve phonological representations gradually becoming more segmental, culminating in access to individual phoneme segments (Fowler, 1991). In contrast, the lexical restructuring hypothesis does not specify the precise level of representation (i.e., phonetic features vs. phonemes) reached during the restructuring process. Although it is difficult to precisely document the timeline of this segmentation process, Fowler (1991) proposed it takes place from around 1- to 8-years-of-age. Walley (1993) also emphasised that the restructuring process is not a global process that affects all words in a child's vocabulary. Some words will be affected before others and in some cases only partial segments of words will be specified in detail.

The segmentation hypothesis specifies that phonemes are not the original basic units of representations. Fowler (1991) stated that children's early phonological representations that underlie speech perception and production are "...stored and retrieved as a holistic pattern of interacting elements, variously described as gestures, features, or articulatory routines." (p.102). This suggests that young infants may be capable of performing well on speech discrimination tasks and produce early words that are adult-like, yet not have phonological representations that contain or involve access to phoneme-sized segments. This is also consistent with early speech perception research that has indicated the storage of gestural information is likely to facilitate a child's ability to discriminate speech sound contrasts (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992).

These hypotheses highlight the role of syllables as units of speech perception and production. Fowler (1991) proposed that segmentation process may be observed by the refinement of articulation movements or *speech gestures* (as measured by acoustic analysis) within syllables. Initially, young children's speech gestures may lack refinement and influence the whole syllable. Over a period of time these gestures are thought to become more finely tuned so that their sphere of influence is reduced to sub-syllable components such as onset and rime units, and eventually to phoneme-sized units (Fowler, 1991; Jusczyk, 1992). Several studies investigating perception and production in children and adults have provided evidence for the restructuring of syllable segments (Krause, 1982a, 1982b; Nittrouer & Studdert-Kennedy, 1987; Nittrouer, Studdert-Kennedy, & McGowan, 1989; Zlatin & Koenigsknecht, 1976). Nittrouer and colleagues (1987, 1989) investigated children and adult's ability to discriminate between /s/ and /ʃ/ when paired with /i/ and /u/ vowel sounds during perception and production tasks. On the perception task, children aged 3, 4 and 5 years were more likely to use information from the following vowel sounds to determine the initial fricative sound. The authors interpreted this finding as younger children attending more to complete syllables or words. In contrast, children aged 7 years and adults were more likely to use frequency information contained within the fricative sound itself to perceive that sound (Nittrouer & Studdert-Kennedy, 1987; Nittrouer et al., 1989). Participants' speech production of the same sound contrasts was then analysed. Acoustic analyses revealed that the younger children's production of /s/ and /ʃ/ were not as differentiated as older children and adults, and were more likely to be influenced by formant transitions to the following vowel sound. These findings were interpreted as evidence that children's early speech productions are based on representations that are at least at the syllable level and gradually become more differentiated over time. The proposed restructuring of phonological representations also reflects developmental changes in young children's phonological awareness (Swan & Goswami, 1997; Treiman & Zukowsky, 1991).

Both the segmentation and lexical restructuring hypotheses highlight the relationship between young children's performance on phonological awareness tasks and underlying phonological representations (Fowler, 1991; Walley, 1993; Metsala & Walley, 1998). The hypotheses advocate that phonological awareness tasks involving sub-syllabic units such as onsets, rimes, and phonemes will be challenging for children until the underlying phonological representations for the words being examined are segmented at an appropriate level of detail. These hypotheses also have implications for children with speech impairment. If children with speech impairment experience faulty or immature phonological processing it is possible their restructuring of phonological representations may be delayed compared to children without speech impairment. This is likely to influence their ability to develop effective reading and spelling skills.

1.11.2 Distinctness hypothesis

The *distinctness* hypothesis proposed by Elbro et al. (1994, 1996) further defines the relationship between phonological representations and reading acquisition. Elbro (1996) introduced the term *distinctness* to describe an important conceptual aspect of underlying phonological representations. The distinctness hypothesis suggests the cause of word decoding difficulty in reading development is phonological representations that do not contain sufficient level of detail to enable the differentiation of words in a child's lexicon.

Distinctness refers to the degrees of difference or separateness of a word's phonological representation from similar words and the amount of phonological information stored with the word (Elbro, 1996). A word with many phonological features that can be used to differentiate it from other words in the child's lexicon is considered more distinct than words with many similar phonological features. For example, a word such as *voice* is likely to be more distinct from its lexical neighbours than *light* since light has a greater number of words with the same phonological rime pattern (e.g., *fight, bite, kite, sight, might, light, night, right, tight*). This hypothesis is consistent with evidence of neighbourhood density affecting word recognition (Luce & Pisoni, 1998; Newman, Sawusch, & Luce, 1997). The hypothesis also states that words may be specified at different levels of distinctness (e.g., *elephant* could be stored as /ælɪfɪt/, /ælifɪnt/, /ælɪfænt/, /aufɪnt/ and /aufɪt/). According to Elbro (1996) phonological awareness and subsequent reading development are affected when phonological representations lack *completeness*. For example, some representations may not be specified in their most distinct form leading to poor differentiation between other words (e.g., *an* and *and* could both be represented as /æn/) (Elbro, 1996).

The distinctness hypothesis proposes that children who have indistinct phonological representations are likely to perform poorly on a range of phonological processing tasks such as pronouncing words and consciously manipulating a word's segmental components (Elbro et al., 1998). As written words are usually representative of the most distinct spoken form of words (Elbro, 1996), children with poorly differentiated or limited levels of representation may be more likely to experience spelling difficulties. Indistinct phonological representations are also likely to negatively affect the retrieval of words during activities such as confrontational naming tasks (Katz, 1986; Snowling, van Wagtendonk, & Stafford, 1988).

The distinctness hypothesis is supported by findings from a study that measured two groups of Danish children's performance on language, cognitive, phonological awareness, and phonological representation tasks (Elbro et al., 1998). The groups consisted of 49 children considered at risk of developing a reading disorder (i.e., due to a genetic disposition for dyslexia) and 42 children with typical development. Children were first assessed at age 6 (i.e., one year before formal reading instruction begins in Denmark) and again two years later. This study included the use of a novel task that involved training children to teach a hand-held puppet how to pronounce names of pictures correctly. In an attempt to obtain the most distinct pronunciation of words, children were told the puppet had both a speech and hearing impairment. Nine multi-syllable Danish nouns were selected as stimulus items. In-depth analyses of the children's most accurate productions were performed. Analyses included –

- Accuracy; the percent of spoken words accepted as *normal*, based on acceptable productions contained in a Danish pronunciation dictionary.

- Control score; the percent of words spoken that were representative of the word's written form.
- Distinctness; a percentage score was obtained by analysing expected and produced vowel productions for omissions or reductions (e.g., a full vowel being reduced to a schwa). A distinctness score of 100% would require a child to produce each vowel in its most distinct form (e.g., *crocodile* said as /krɒkoudail/). When children omitted or reduced reducible vowels (e.g., *crocodile* said as /krɒkədail/), the score was lowered (Elbro et al., 1998).

Children's distinctness scores and performance on letter naming and phoneme identification tasks, recorded at age 6, were predictive of phonological awareness ability at age 8. Children who had the greatest difficulty producing the most accurate production of words on the distinctness task were also more likely to be identified as having dyslexia at age 8 (Elbro et al., 1998). The authors attributed this relationship to the quality of underlying phonological representations of words. The study demonstrated the usefulness of a novel assessment paradigm to obtain children's most accurate production of words.

Foy and Mann (2001) utilised a similar task to Elbro et al.'s (1998) distinctness task to examine the relationship between phonological representations and phoneme awareness skills. A range of tasks examining phonological representations and phonological awareness were presented to 40 children aged 4- to 6-years with typical development. Children were classified as readers, non-readers with some phoneme awareness skills and non-readers with no phoneme awareness skills. No significant group differences were observed on the distinctness task. Analysis of children's productions on this task, however, only included a gross measure (i.e., correct or incorrect). This analysis may have reduced the effectiveness of the task in determining differences between children with and without phoneme awareness skills. Even with this gross analysis, the difference in performance between children classed as readers and children with no phoneme awareness skills approached statistical significance (p = 0.07). This result reinforced Elbro et al.'s (1998) argument for an in-depth analysis of vowel productions to determine discrete differences in children's underling representations, as even fine-grained variations in a word's phonological representation may impact on reading and spelling performance.

1.12 Assessment of Phonological Representations

1.12.1 Speech production tasks

A range of speech production tasks have been used to draw inferences on underlying phonological representations in children and adults with reading disorders (Elbro, 1996; Snowling et al., 1988) and children with specific language impairment (Edwards & Lahey, 1996). Speech production tasks examine children's phonological systems by attempting to elicit their best production of single words or nonwords. Naming tasks are presented in several formats. Presenting a series of pictures and asking subjects to name the objects pictured is known as confrontation naming (Snowling et al., 1988). Picture naming assumes that accurate speech sound information must be obtained from well-specified phonological representations (Swan & Goswami, 1997). Variants of naming tasks include requiring a child to name a series of pictures as quickly as possible (Katz, 1986) or identifying an object from its verbal description (Snowling et al., 1988). Children with reading impairment demonstrate weakness in naming pictures, numerical digits and shapes (Elbro, 1996; Snowling et al., 1988).

Performance on nonword repetition tasks has also been used to provide support for efficient or impaired lexical systems and poor phonological representations (Edwards & Lahey, 1996; Fowler, 1991; Larivee & Catts, 1999). Nonword repetition tasks investigate children's phonological and lexical skills without the confounding influence of word familiarity (Snowling, 1981). Fowler (1991) argued that poor nonword processing indicates a weakness in integrating phonological stimulus into a cognitive form that is readily accessible for production purposes. This weakness may result in unstable representations developing for real words and lead to difficulty preparing articulatory codes for production (Swan & Goswami, 1997). Conversely, Metsala (1999) reported that nonword repetition skill is a function of vocabulary size, encompassing the number of words known, familiarity of words, and similar sound characteristics between words.

Production-based tasks, however, are of limited use when attempting to identify children with speech difficulties who may also have poorly specified phonological representations. Although many children with speech impairment experience difficulty learning to read and spell, many of these children perform at age-appropriate levels (Nathan et al., 2004), indicating the presence of well-specified phonological representations. The use of production-based tasks to identify at-risk children will therefore result in a number of false positive identifications. This creates a need to examine receptive tasks that provide information on underlying phonological representations and eliminate the influence of speech output difficulties on task performance.

1.12.2 Speech perception tasks

A number of studies have investigated the performance of children with speech impairment or children at risk of reading disorder on receptive judgment or mispronunciation detection tasks (Bird & Bishop, 1992; Carroll & Snowling, 2004; Edwards & Lahey, 1996; Larivee & Catts, 1999; Rvachew et al., 2003). Although these tasks provide insight into the nature of underlying phonological representations, most of these studies did not specifically investigate phonological representations. Bird and Bishop (1992) reported 5- and 6-year-old children with speech impairment performed poorly compared to age-matched controls on speech discrimination tasks requiring judgment of mispronounced real and nonwords as well as initial phoneme identification and matching. The researchers concluded that the poor performance on these tasks was due to children with speech impairment not being able to analyse segmental aspects of words (Bird & Bishop, 1992). Edwards and Lahey (1996) investigated children with specific language impairment (SLI), children with speech impairment and a control group on a timed task that required children to identify sound sequences that represented real words. The researchers reported that children with SLI were slower at identifying correct sound sequences than children with and without speech impairment. These studies did not discuss the potential involvement of phonological representations in children's task performance.

Recent studies have focused on examining phonological representations in children with speech impairment using receptive tasks to avoid the influence of speech errors on task performance (Carroll & Snowling, 2004; Rvachew et al., 2003). These tasks have involved children listening to auditory stimuli and making a behavioural response (e.g., pointing to a picture) based on their perception of the stimuli. Rvachew et al. (2003) assessed phonemic perception in 13 children with speech impairment using a task developed on Speech Assessment and Interactive Learning System (SAILS) software (Avaaz Innovations, 1997). The 70 task items were productions of four single syllable words (*lake*, *cat*, *rat*, *Sue*) spoken by a range of adults and children. Stimuli consisted of either correctly pronounced words or words with a misarticulated initial phoneme (e.g., *lake* said as *wake*). Children were trained to point to either a picture of the target word to indicate a correct production or a large cross to indicate an incorrect production. Children with speech impairment performed poorly compared to matched controls on this task. The reduced performance was attributed to poor quality underlying phonological representations of the target words (Rvachew et al., 2003). This finding provided evidence for the relationship between phonological representations and speech production.

1.13 Chapter Summary

This review of the literature has identified the importance of phonological representations to a range of spoken and written language skills. Young children must store and access speech sound information associated with words in order to develop spoken word recognition skills. Sometime around 12-months-of-age, early phonological representations begin to support the appearance of spoken words from their native language. The intertwined processes of speech perception and speech production then contribute to the ongoing specification of words' speech sound components in long-term memory. As phonological representations are considered the basis for the production of spoken words (Stackhouse & Wells, 1997), children with speech impairment may have difficulty in accurately storing phonological representations. The influence of developing phonological representations on improvements in speech production, however, is yet to be examined.

Phonological representations influence phonological awareness and early reading development (de Gelder & Vroomen, 1991; Katz, 1986; Snowling et al., 1988). Developmental changes in phonological representations may facilitate children's ability to perform phonological awareness tasks. Children who demonstrate good phonological awareness skills, particularly the manipulation of phoneme segments, typically become more competent readers. These children can efficiently access phonological representations containing segmental information and integrate this phonological information in order to identify printed words (McGuinness, 1997). Elbro et al. (1998) provided evidence for a relationship between indistinct phonological representations and phonological awareness deficits. Six-year-old children considered at risk of reading disability demonstrated poor performance on a task requiring the production of the most distinct form of multisyllable Danish words. Two-years later, children who performed poorly on this task were more likely to demonstrate phonological awareness deficits (Elbro et al., 1998).

There is a need to investigate the phonological representations of young children with speech impairment as they are known to be at significant risk of reading disability (Nathan et al., 2004). A first step in this process is an examination of the use of receptive assessment measures to determine characteristics of underling phonological representations. Children with speech impairment will have difficulty performing tasks designed to measure phonological representations based on speech output. Tasks that rely on the perception and judgment of spoken words may offer more accurate insights. The development of tasks using a wider array of stimuli, than presented during previous studies, will also provide a more complete description of children's phonological representations.

1.14 Overview of Study Aims and Hypotheses

This thesis reports a series of studies that investigated the relationship between phonological representations, phonological awareness, and early print decoding in children with moderate to severe speech impairment. The studies address the following aims:

1. To determine the effectiveness of receptive phonological representation measures in identifying group differences between children with moderate or severe speech impairment and children with typical speech development;
2. To monitor children's changes in performance on measures of phonological representations, phonological awareness, and speech over an 18-month period covering the period immediately before and after initial exposure to formal reading instruction;
3. To examine the relationships between performance on phonological representation tasks and performance on speech, phonological awareness, and early print decoding tasks;
4. To explore the relationship between the development of phonological representations and phonological awareness in a child with cerebral palsy who had limited verbal output.

Chapter two describes three novel receptive judgment tasks developed to examine children's underlying phonological representations. These tasks were presented to nine children with moderate to severe speech impairment and 17 children with typical speech development. The hypothesis tested was that children with speech impairment would perform poorly on these tasks compared to children without speech impairment and that there would be a positive relationship between participants' performance on the phonological representation tasks and performance on speech production and early phonological awareness measures.

Chapter 3 reports a longitudinal study following the participants from the first assessment trial for an 18-month period until they were approximately 6-years-of-age. Assessments were administered at six-monthly intervals with a total of four assessment trials. Measures of speech production, phonological representations, letter-sound knowledge and phonological awareness were taken at each study trial. Measures of early printed word and nonword decoding were also presented at the 3rd and 4th trials. It was hypothesised that children with speech impairment would demonstrate reduced performance on measures of phonological representations and phonological awareness at each assessment trial and on the early reading measures at the final two trials compared to children with typical speech development and that a stable relationship between these variables would be evident over time. It was also expected that children's speech production skills would improve at each trial, but significant differences between groups would remain at the final trial.

The participants' performances on receptive phonological representation tasks presented under different experimental conditions are detailed in chapter 4. The first condition involved presentation of auditory stimuli with and without supporting pictures, to determine the influence of visual support in accessing phonological representations. The second condition investigated the effect of lexical neighbourhood density and frequency of word use on a receptive mispronunciation judgment task. The hypothesis tested was that children with speech impairment would experience greater difficulty than children with typical speech development in the auditory-only condition and when judging the accuracy of infrequently used words from sparsely populated lexical neighbourhoods.

The individual performances of children with speech impairment on all tasks presented at each assessment trial are reported in chapter 5. In-depth analyses of four children with speech impairment are also presented: Two children with delayed speech development, a child demonstrating consistent deviant speech impairment, and a child with persistent and inconsistent speech error patterns are examined. Their performance on speech, phonological representation, phonological awareness, and early decoding measures is compared to children with typical speech development. The hypotheses tested included: The child with consistent deviant speech impairment would perform poorly on measures of phonological representations and phonological awareness compared to the children with delayed speech development and inconsistent speech impairment; and the child with inconsistent speech impairment would demonstrate inferior performance at each trial compared to children without speech impairment and the two children with delayed speech development.

Chapter 6 details the performance of an older child (i.e., age = 11:09 at trial 1) with cerebral palsy and CCN, on receptive phonological representation, phonological awareness and print decoding tasks. This child's performance was compared to the children with typical speech development who participated in the longitudinal study. The aim of this case study was to investigate the specification of phonological representations in the absence of effective articulatory feedback. It was hypothesised that this child would demonstrate inferior performance on all measures in comparison to younger children with typical speech development.

The thesis concludes with a general discussion of the studies' main findings, implications for the clinical assessment and treatment of children with speech impairment, and proposed directions for future research.

Chapter 2. The Use of Receptive Tasks to Examine Underlying Phonological Representations

2.1 Introduction

Many children with speech impairment experience phonological awareness and word recognition difficulties (Carroll & Snowling, 2004; Rvachew et al., 2003). Nathan et al. (2004) identified 47% of children with speech impairment at age 4 as demonstrating inferior reading and spelling ability at age 7. Conversely, it may be argued that up to 50% of children with speech impairment are succeeding in early reading acquisition. There is a need, therefore, to understand factors that contribute to the variable reading outcomes reported for this population. Investigating the quality of these children's underlying phonological representations of spoken words and how this information is stored in long-term memory may provide insight into this issue. Poor quality phonological representations are thought to prevent children at risk of dyslexia, from accessing phoneme-level components of words during phonological awareness and early print decoding tasks (Swan & Goswami, 1997; Elbro, 1996; Elbro et al., 1998). Understanding if similar difficulties are evident in children with speech impairment may help to elucidate the relationship between speech impairment and reading disability.

Investigations are needed to specify assessment measures that provide information on the nature of underlying phonological representations. As children with speech impairment are disadvantaged on production-based tasks, the development of valid and reliable receptive tasks designed to evaluate phonological representations is necessary. The study described in this chapter begins to address this need. Novel receptive tasks were trialled together with speech output measures to examine underlying phonological representations in 4- and 5-year-old children with moderate or severe speech impairment. Children's performance in these tasks was compared to children with typical speech development. The relationships between measures of speech production, phonological representations, and early phonological awareness ability were also examined. The study investigated the following research questions -

1. Are there group differences between children with moderate or severe speech impairment and children with typical speech development on receptive phonological representation measures?
2. Do children's performance on phonological representation tasks correlate with performance on measures of speech production and phonological awareness?

The experimental tasks developed in this study to examine children's phonological representations and word recognition skills, were based on previously reported measures that required speech output (Carroll & Snowling, 2004; Elbro et al., 1998; Grosjean, 1980). Developed by Grosjean (1980), the gating paradigm has been employed to investigate spoken word and phonemic perception skills in children with language, phonological, and reading disorder (Metsala, 1997b; Walley, Michela, & Wood, 1995; Wesseling & Reitsma, 2001). Gating paradigm tasks have required subjects to identify single words by listening to increasingly longer segments of a word's acoustic signal. The term *gate* refers to the point at which the acoustic signal is cut-off during presentation. For example, Metsala (1997b) initially presented the first 100ms of single syllable words then increased the length of the signal by 50 ms on subsequent *gates*. Participants were instructed that they would hear the beginning of a word, followed by gradually increasing amounts of the word. After each presentation, participants were asked to identify (i.e., speak) the target word. Performance on gating tasks by younger children (i.e., 6-7 years) was predictive of their level of reading ability (Metsala, 1997b).

Wesseling and Reitsma (2001) also presented a gating paradigm task to investigate the development of reading skills and phonological representations in typically developing Dutch children. Ninety-one children aged 5- to 6-years participated in these two-year longitudinal studies. Inconsistent results from the gating tasks were reported and the researchers concluded that the gating paradigm was not a suitable measure to determine the quality of phonological representations. The correct identification and production of a *gated* word before the delivery of all acoustic information is likely to test the accessibility of underlying phonological representations. As speech output is required, however, weaknesses in components of the motor speech system may influence performance on this task.

Receptive assessment tasks provide a valuable alternative to speech-production tasks for children with speech impairment. For example, tasks that require children to judge the pronunciation accuracy of a target word may provide information on underlying phonological representations. Mispronunciation detection tasks require children to look at a picture and listen to spoken words. If the spoken word is perceived as a correct pronunciation of the pictured item, children are expected to point to a symbol indicating a correct judgment (Rvachew et al., 2003). Carroll and Snowling (2004) presented a mispronunciation detection task using a handheld puppet to deliver stimuli using live-voice and without picture stimuli. Children were required to respond by saying either *right* or *wrong*. Example stimuli included *gorilla* which was mispronounced as *golilla* and *mouse* mispronounced as *moush*. Children with speech impairment performed poorly compared to children with typical speech development on both mispronunciation detection tasks (Carroll & Snowling, 2004; Rvachew et al., 2003).

Methodological issues associated with presentation of mispronunciation detection tasks support the need for further examination of the use of these tasks with children with speech impairment. Rvachew et al. (2003) employed the use of four single-syllable words and altered the initial phoneme to create mispronounced target words (e.g., the word *lake* was mispronounced as *wake*). The presentation of *wake* with a picture of a lake may have caused confusion for some children. Although *wake* is not an appropriate corresponding word for a picture of a lake, it is a real word, and likely to activate an existing phonological representation. The speech error (i.e., /l/ → /w/) is also a common speech error pattern that may be late to suppress. This substitution, therefore, may be difficult to perceive for some children. Participants' speech production was also highly variable. Percent consonant correct scores for children with speech impairment ranged from 40% to 79% (Rvachew et al., 2003). Similarly, children with speech impairment in Carroll and Snowling's (2004) study produced PCC scores ranging from 25% to 96%, with 4 children presenting with mild or resolved speech error patterns (i.e., PCC scores of between 80% and 96%). In both studies, superior performance by children with mild-moderate speech impairment is likely to have masked difficulties that children with more severe speech impairment experienced on the tasks. The wide range of children's ages (i.e., 3:11 to 6:6) in Carroll and Snowling's (2004) study may also have resulted in the performance of older children masking difficulties among younger children.

Carroll and Snowling (2004) also presented a *phonological learning* task that involved teaching a series of words to children and then examining children's ability to recognise and spontaneously speak the word. Children with speech impairment performed poorly compared to children with typical speech development on this task. The stimuli used for this task were real words such as *wart*, *tusk* and *amber*. Some children between the ages of 3:11 and 6:6 are likely to be familiar with these words. Word familiarity, however, was not examined prior to testing. The current study extends this task further with the development of a specific nonword learning task that examined children's ability to develop and reflect on new phonological representations.

The current study also adds to the research by developing two additional receptive tasks to investigate children's phonological representations. This included the development of a receptive phonological representation judgment task. This task examined additional aspects of underlying phonological representations such as the representation of vowel sounds within multisyllable words and the use of a wider range of stimuli. The development of a receptive version of the gating paradigm is also reported. The study considers performance on these tasks with speech production measures including real and nonword repetition tasks. Performance on the phonological representation tasks is also compared with early phonological awareness development. The specific hypotheses for the research questions examined were -

1. Children with speech impairment will demonstrate poor performance on the novel receptive tasks compared to children with typical speech development;
2. Across both groups, children's performance on receptive phonological representation tasks will correlate with performance on early phonological awareness measures and speech production skills. As some children with poor speech production are able to demonstrate phonological awareness, it was not expected that speech production and phonological awareness ability would be well correlated.

2.2 Method

2.2.1 Participants

Children with speech impairment were referred to the study by local kindergarten and preschool teachers, and speech-language therapists. These agents were asked to refer any child between 4- and 5-years-of-age who demonstrated speech that was very difficult to understand and who spoke standard New Zealand English as their first and only language. On referral, each child's speech was assessed using the procedures described below. Children in the control group were recruited by random selection from local kindergarten and preschool attendance lists. Participants were required to meet the following criteria:

1. No history of sensory, neurological, physical, or intellectual impairment;

2. Age appropriate receptive vocabulary knowledge as evidenced by standard scores between 85 and 125 on the Peabody Picture Vocabulary Test - III (Dunn & Dunn, 1997);
3. Standard scores of 8 and above on the receptive language subtests of the Clinical Evaluation of Language Fundamentals – Preschool (Wiig, Secord, & Semel, 1992);
4. Responded to pure-tone thresholds and provided tympanograms within normal limits using pure-tone audiometric testing and tympanometry.

Nine children (1 girl and 8 boys) from the ten children with severe speech impairment were referred to the study and 17 children (7 girls and 10 boys) from the randomly selected 20 children with typically developing speech skills met the inclusion criteria. These children attended kindergartens from suburban middle or upper socioeconomic status areas. The primary caregiver of each child spoke non-accented standard New Zealand English. No statistically significant differences at $p<0.05$ or below were observed between groups on the inclusion criteria of age, PPVT–III and CELF-P receptive language subtest standard scores. A summary of group characteristics is provided in Table 1.

2.2.1.1 Speech assessment

Children's speech production was measured using the Goldman-Fristoe Test of Articulation (GFTA) (Goldman & Fristoe, 1986) and the 25 words from the inconsistency assessment subtest of the Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd, Crosbie, Zhu Hua, Holm & Ozanne, 2002). Children were required to spontaneously name pictures presented for both tasks. The GFTA contained 45 words consisting of mostly one and two syllables (e.g., *knife, duck, rabbit,* and *wagon*). Three items contained 3 syllables (e.g., *telephone* and *pyjamas*). These words included a total of 124 consonant and 64 vowel phonemes. The 25 words from the subtest of the DEAP included 12 single (e.g., *fish, boat*, and *bridge*) and 13 multisyllable (e.g., *helicopter, bridge,* and *dinosaur*) words, consisting of 82 consonant and 49 vowel sounds.

Children were trained on the 25 words from the subtest of the DEAP prior to testing, to ensure word familiarity. If children were unable to spontaneously name target pictures during testing, delayed modelling techniques were used to stimulate responses. This included the provision of phonemic or semantic prompting (e.g., a phonemic prime for the word *butterfly* was "*this is a /b/*"; and, a semantic prime for the word *kangaroo* was *"an animal that bounces"*). Prompting alternated between phonemic and semantic priming. If children were unable to name the target picture after prompting, the target word was modeled and children asked to imitate the word. The item was then presented again after presentation of 3 further words. All responses were transcribed using a broad phonetic transcription and analyzed using the *Computerized Profiling* (*CP*) software (Long, Fey, & Channell, 2004). The total percent of consonants correct (PCC) was computed (Shriberg, Austin, Lewis, & McSweeny, 1997). Children with speech impairments (SI Group) produced significantly lower PCC scores than children with typical speech development (TS Group) ($p<0.001$) as shown in Table 1

The verification of the transcription of children's speech involved the following process. Initially, children's speech was transcribed online using broad transcription techniques and recorded using a digital tape recorder (Sony Digital Audio Tape-corder TCD-D8). Recordings were then reviewed to establish inter-judge reliability. An independent examiner experienced in phonetic transcription of disordered speech, reviewed productions by all children in the speech impairment group and four children in the control group. All productions were scored as correct or incorrect on a point to point basis. The level of agreement reached between examiners ranged from 100% (i.e., for 2 control children) to 89% (i.e., a child with speech impairment) of words transcribed. Each disputed item was resolved by the two examiners repeatedly listening to the production and discussing interpretations until 100% agreement of the transcribed utterance was reached.

Table 1. *Group characteristics at trial 1*

	SI group		TS group			
	M	SD	M	SD	*P* value	Cohen's *d*
Age (months)	53.33	6.50	55.88	2.39	0.156	0.521
PPVT-III	107.78	10.89	107.41	5.75	0.909	0.043
PCC	38.89	12.00	90.94***	7.68	<0.001	5.167
Linguistic Concepts[1]	12.67	2.18	12.76	1.92	0.914	0.044
Basic Concepts[1]	12.11	2.09	11.88	1.65	0.760	0.122
Sentence Structure[1]	12.44	3.09	11.18	2.40	0.260	0.455

Note. SI group = Speech impairment group; TS group = Typical speech development group; PPVT-III = Peabody Picture Vocabulary Test III (Dunn & Dunn, 1997); PCC = Total percentage of consonants correct; [1]Receptive language subtests from the Clinical Evaluations of Language Fundamentals-Preschool (Wiig, et al., 1992), standard scores are reported. Effect size descriptors (Cohen, 1988); *Large* (d > 0.8); *Medium* (d = 0.5 to 0.8); *Small* (d = 0.2 to 0.5).
***p<0.001.

2.2.2 Procedures

Assessment tasks designed to examine phonological representations, phonological awareness, and speech production were presented to each participant. Children were assessed individually in a quiet university clinic facility. Each assessment session was video and audio taped for reliability and scoring purposes. The assessments presented are detailed below.

2.2.2.1 Receptive phonological representation tasks

Three receptive tasks were developed to investigate participants' underlying phonological representations. Each task was developed using Microsoft® PowerPoint® slide presentation with a combination of picture and sound stimuli. The slides were presented on a notebook computer (Acer TravelMate320 with a Celeron(R) CPU 2.0GHz processor and

256MB of RAM) using Powerpoint®. All speech stimuli were produced by a male native New Zealand English speaker and were digitized at 22kHz using a commercially available speech analysis system (Kay CSL-4300B). Edited stimuli were then stored as *.wav* files on the computer's hard disk drive. Stimuli for the *gating* task described below were edited using PRAAT v4.2.04 software (Boersma & Weenik, 2004) to eliminate redundant acoustic signals before and after the target stimuli.

Experimental tasks were first piloted with three children with typical development aged between 4 years 8 months and 4 years 11 months. These test presentations were made to ensure that task requirements were within the capability of preschool children, and that picture stimuli used were appropriate for this age group. The tasks were also presented to five adults to ensure that speech stimuli were perceived as anticipated (i.e., either correct or incorrect productions of target words). Tasks were modified to accommodate feedback from both adult and child trials. This involved discarding several word productions that adults could not agree on the correctness of the production.

Prior to the presentation of each experimental task, participants were asked to name all stimuli pictures used in the tasks. If a child was unable to name a picture, prompts were provided to help the child produce the target word. As the speech of several children was unintelligible, the examiner used clinical judgment to determine if the child attempted the target word. If children were unable to name the target picture or did not appear to attempt the word, a model was provided and children asked to repeat the picture's name.

2.2.2.1.1 Phonological representation judgment task (PR judgment)

A receptive assessment task that examined children's underlying phonological representations was developed. This task was based on Elbro et al.'s (1998) production task. Elbro et al. (1998) recorded the accuracy of children's production of vowel sounds in multisyllable words to gauge the distinctness of phonological representations. Vowels were measured as they contain significant acoustic energy, and therefore contribute to the development of more distinct phonological representations. Additionally, Thyer and Dodd (2005) reported children with dyslexia demonstrated difficulty utilising acoustic cues in vowel sounds to categorise phonemes. This finding was interpreted as children with dyslexia possessing indistinct phonological representations. The stimuli used in the receptive task developed for this study, therefore, included multisyllable words that had alterations made to vowel sounds.

This task comprised 40 slides that each contained one picture of an object (e.g., watermelon, caterpillar, helicopter), a *happy* face and a large black cross (see Figure 1). Filler slides containing the digits ‘00000’ were placed between each stimulus slide to cue the participants for a new task item. Children used stereo headphones (Sony MDR-V300) connected to the computer with the volume set at a comfortable listening level. Children were instructed that they would see single pictures of the target word and hear a pre-recorded production of the target word. The children were asked to decide if the spoken word was a *good* or *not a good* way of saying the target word. Corrective feedback was provided on the first ten items. Children were then presented with 30 test items (a word list and specific instructions provided are included in Appendix A) and asked to point to either the happy face or black cross to indicate their judgment decision. Each item represented either a good representation of the target (nine items) or had one of the following alterations made:

- All vowel sounds changed (one item). For example, *motorbike* was produced as *mertyboke* (/mɜtibouk/).
- A vowel in a stressed syllable changed (seven items). For example, *dinosaur* was produced as *dunasaur* (/dʌnəsɔ/).
- A vowel in an unstressed syllable changed (six items). For example, *caterpillar* was produced as *catupillar* (/kætupɪla/).

- A vowel deleted from an unstressed syllable (seven items). For example, *kangaroo* was produced as *kangroo* (/kæŋru/).

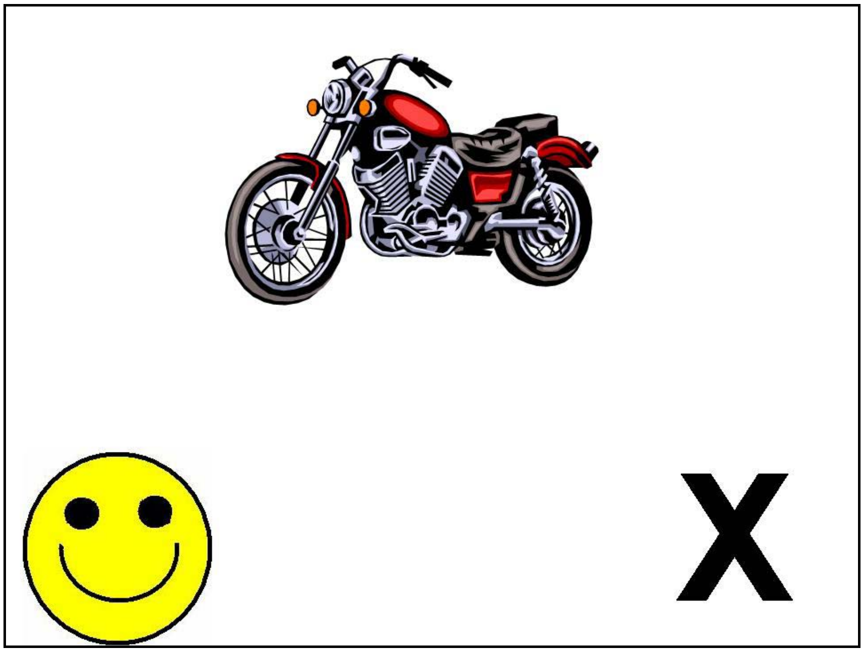

Figure 1. Screen shot of PR judgment item "motorbike". Children were required to listen to pre-recorded spoken stimuli (e.g., /moutəbaik/) and point to the happy face to indicate judgments of *correct* or *incorrect*.

2.2.2.1.2 Nonword learning task (NW learning)

To examine children's ability to create new phonological representations, and then immediately reflect on the representation, a nonword learning (NW learning) task using Powerpoint® slides was developed. These picture slides contained abstract colour objects (see Figure 2) and pre-recorded auditory stimuli. Each object was shown on six different training slides together with the name of the object or a phrase containing the target name (e.g., *this is a blaig*; *the girl is jumping over the blaig*; *big blaig*). After the training slides children were told they would see the object again and hear a pre-recorded production of the target word. The judgment task required children to point to either a green tick or red cross after deciding if the stimulus was a *good* or *not a good* way of saying the target word. Corrective feedback was given during a training task that involved presentation of 6 training slides followed by a set of four judgment slides for the trained nonword. Children were presented with 20 test items (see Appendix B) that consisted of four judgment items for each of five different nonwords. Each item was either a *good* representation of the target or had one of the following alterations made –

- One vowel sound changed (e.g., *melached* (/mælətʃed/) was produced as *mellowched* (/mæloutʃed/)).
- One consonant sound was changed (e.g., *cherfote* (/tʃɜfout/) was produced as *cherfoge* (/tʃɜfoug/)).

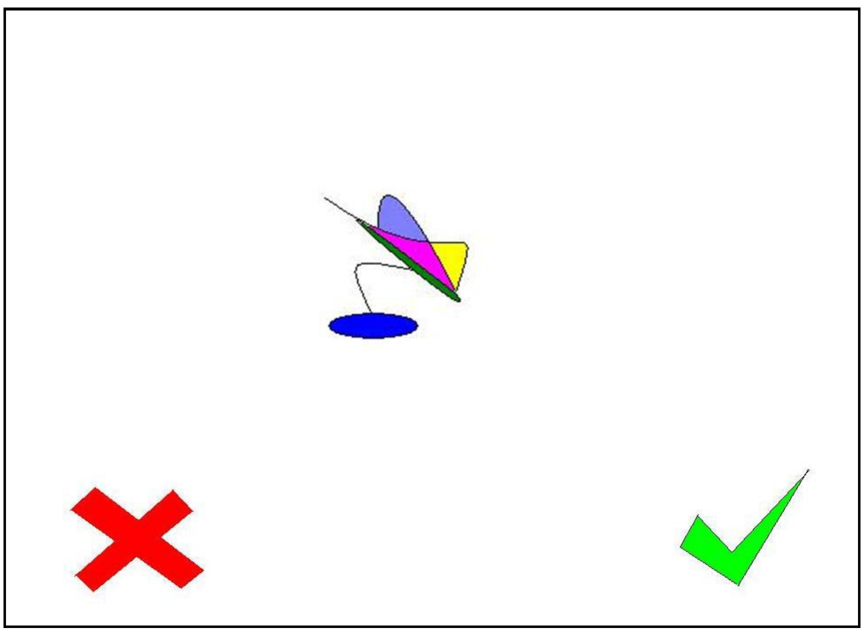

Figure 2. Screen shot of NW learning task item "crepdeesluv". Children listened to pre-recorded spoken stimuli and then indicated their judgment by pointing to either the red cross for incorrectly pronounced stimuli or the green tick for correctly pronounced stimuli.

2.2.2.1.3 Receptive gating task

Previous studies have presented gating paradigm tasks requiring spoken word productions (Grosjean, 1980; Metsala, 1997b). The task developed for the current study was an attempt to develop a receptive task based on the gating paradigm for children with speech impairment. The task was developed by providing three pictures (i.e., one target and two distracter items) on each Powerpoint® slide together with auditory presentation of the gated stimulus (see Figure 3). Nine pre-recorded target words were segmented into *gated* stimuli. A list of target words and length of stimuli presented is included in Appendix C. Three different lengths of acoustic stimuli for each target word were saved. The shortest stimuli for each word included the initial phoneme and a small segment of the first vowel. Subsequent stimuli lengths were the initial length +50ms and +100ms. Each recording started 10ms before the onset of the word's initial phoneme. Due to the variety of initial consonant sounds the length of each stimulus varied. For example, *cup* had 3 recorded stimuli at lengths of 150ms, 200ms, and 250ms. The target word *shark* had stimuli lengths of 240ms, 290ms, and 340ms due to the length of the initial sound /ʃ/. Participants were instructed that they would hear the beginning of a word and were required to point to the target picture.

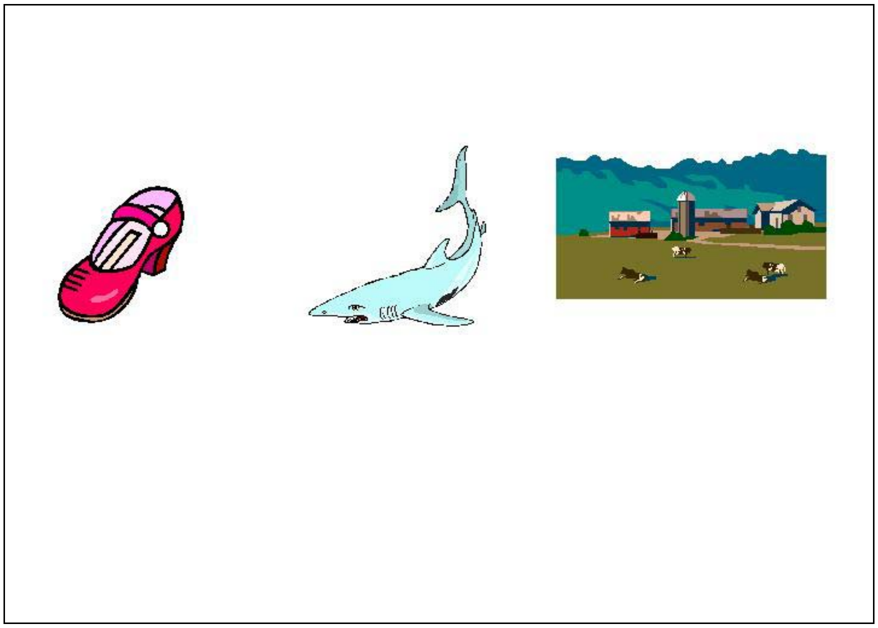

Figure 3. Screen shot of Receptive Gating task item *shark* with distracter items *shoe* and *farm*. Pre-recorded initial acoustic segments of the target word (e.g., first 240ms of shark) were presented to children. Children were required to point to the picture corresponding with the perceived word.

2.2.2.2 Test Item and scoring reliability

All data obtained from the presentation of the three receptive phonological representation tasks were analysed to examine the reliability of test items used. A classical item analysis of correct and incorrect responses on each task was undertaken. Internal consistency reliability for the PR judgment task yielded a coefficient alpha $a = 0.835$ which met the most stringent measure of internal consistency (i.e., $a = 0.8$; Nunally, 1978). The receptive gating task also showed high internal consistency ($a = 0.7$). The NW learning task, however, showed less favourable internal consistency ($a = 0.46$). Item analysis indicated that three items from one set of stimuli showed poor reliability. As most participants found these items difficult and scored incorrect responses, the items were removed from the data set. The revised data showed more acceptable levels of reliability (*a* = 0 .601) and was used for statistical analyses.

An independent examiner reviewed videotapes of four participants (i.e., two randomly selected children from the SI group and two children from the TS group) performing the receptive gating, PR judgment and NW learning tasks. The independent examiner was asked to judge whether a child responded correctly or incorrectly to each item presented based on a prepared score sheet for each task. The examiner's records were then compared with the participants' original score sheets. No differences were observed between the independent examiner's scores and original scores providing an inter-rater reliability score of 100% for each task.

2.2.2.3 Real and nonword repetition task

To contrast the receptive assessments tasks, two repetition tasks were used to provide information on children's phonological processing of multisyllable real and nonwords. Each child was provided with a model of 10 real words and 10 nonwords for repetition. The stimulus words and instructions provided for each child are included in Appendix D. Both sets of stimuli were developed to ensure that a wide range of speech sounds were covered within each set. The recording, transcription, and verification procedures used for the speech assessment tasks were repeated for this task.

2.2.2.4 Phonological awareness

The Preschool and Primary Inventory of Phonological Awareness (PIPA; Dodd, Crosbie, McIntosh, Teitzel, & Ozanne, 2000) was administered to measure the following phonological awareness skills -

1. Syllable segmentation (p. 2 of test booklet). For example "When we say words we can say them in drumbeats. We can say ***puppy*** like this - /pʌ/…/pi/. Now you do it."

2. Rhyme awareness (p. 3). For example, after a period of training the concept of rhyme items are presented with the instruction “show me the picture that doesn’t belong.” Pictures for the first training item were w*all, fall, ball,* ***cat***.
3. Alliteration awareness (p. 4). For example, “Three of the words start with the same sound. One doesn’t. See if you can work out which one doesn’t belong.” Pictures presented for test item 5 were *cage, cup,* ***sun,*** and *cow.*
4. Phoneme isolation (p. 5). For example, a picture of a flower was presented with the instruction “Tell me the first sound of ***flower***.”
5. Phoneme segmentation (p. 6). For example, the training item *pig* was presented with the instruction “Pig. I’m going to say ***pig*** with counters, /p/…/ɪ/…/g/. This time you’re going to do it without pictures.” A correct score required accurate oral segmentation of each phoneme.
6. Letter knowledge (p. 7). For example, the instruction “Do you know what sound this letter makes?” was presented to children. Thirty-two single letters (e.g., *b, m*, and *t*) or double letter combinations (e.g., *sh, fl*, and *sw*) were presented.

The examiner carefully followed the administration and scoring procedures outlined in the test manual. The technical information reported in the test manual indicates the PIPA has strong psychometric properties (see pp. 21-26 for details). The internal consistency of subtests is strong with reliability coefficient alpha scores above an acceptable level of 0.7 (Dodd et al., 2000).

2.3 Results

2.3.1 Phonological representation tasks

The data were analysed to compare the performance of the two groups on the phonological representation tasks. A multivariate analysis of variance indicated a significant group difference [$F(5,20) = 34.59$, $p<0.001$]. Inspection of univariate tests indicated a significant difference for the PR judgement task [$F(1,24) = 6.17$, $p<.05$]; NW learning task [$F(1,24) = 5.29$, $p<.05$]; real word repetition [$F(1,24) = 152.47$, $p<.0001$]; and, nonword repetition [$F(1,24) = 103.21$, $p<.0001$]. There was no statistically significant group difference for the receptive gating task [$F(1,24) = 0.65$, $p=0.427$]. Descriptive and effect size data are shown in Table 2. Cohen's *d* effect size estimates were considered large ($d>0.80$) for the PR judgment task ($d = 0.9583$) and NW learning task ($d = 1.2584$). A small effect size ($d = 0.320$) (Cohen, 1988) was calculated for the receptive gating task. The very large effect size estimates of the real word ($d = 4.830$) and nonword ($d = 4.005$) repetition tasks suggest that these tasks may overestimate differences in phonological representations due to the need for speech output.

Table 2. *Group performance on phonological representation tasks*

	SI group	TS group	P value	Cohen's *d*
PR judgment task				
(*n* = 30 test items)				
M	18.00	23.24	0.0202*	0.958
SD	6.42	4.31		
Range	10-27	12-29		
NW learning task				
(*n* = 17 test items)				
M	12.33	15.24	0.0034**	1.258
SD	2.69	1.86		
Range	8-17	12-17		
Receptive gating task				
(*n* = 27 test items)				
M	19.67	20.88	0.4290	0.320
SD	4.15	3.37		
Range	13-25	16-27		
Real word repetition (PCC)				
M	38.67	88.41	P<0.0001	4.8304
SD	11.73	8.63		
Range	19-56	69-100		
Nonword repetition (PCC)				
M	37.56	84.06	P<0.0001	4.0046
SD	13.01	10.02		
Range	20-58	58-97		

Note. SI Group = Speech impairment group; TS Group = Typical speech development group.

**p*<0.05, ***p*<0.01

2.3.2 Phonological awareness

Group performance on the phonological awareness subtests of the PIPA were compared using separate univariate analyses of variance. The only significant group difference observed was for the phoneme segmentation task [$F(1,24) = 6.17$, $p = 0.02$]. Floor effects, however, contributed to this finding with the average score for children in the SI group recorded as 0.33 (SD = 1.00) and children in the control group recording an average of 1.82 (*SD* = 1.63). A group comparison on PIPA subtests is shown in Table 3. A comparison of the participants' performance against the normative data provided with the PIPA, however, suggested that the majority of the children with speech impairment were at risk of phonological awareness deficits as six of the nine children (66%) performed one standard deviation or more below the mean standard score expected for their age level on at least two of the PIPA subtests. In contrast, the performance of only 4 of the 17 children (24%) without speech impairment was identified as being of concern.

Table 3. *Mean group scores from the PIPA subtests*

	SI group	TS group	P value	Cohen's *d*
Rhyme				
M	3.67	4.82	0.3414	0.403
SD	2.78	2.92		
Alliteration				
M	3.67	3.88	0.8525	0.071
SD	3.54	2.18		
Syllable				
M	5.00	5.24	0.8769	0.062
SD	4.36	3.35		
Isolation				
M	3.22	4.06	0.6388	0.194
SD	4.49	4.18		
Segmentation				
M	0.33	1.82	0.0200**	1.102
SD	1.00	1.63		
Letter Knowledge				
M	5.33	5.18	0.9611	0.019
SD	9.07	6.39		

Note. SI Group = Speech impairment group; TS group = Typical speech group; Rhyme = Rhyme Awareness; Alliteration = Alliteration Awareness; Syllable = Syllable Segmentation; Isolation = Phoneme Isolation; Segmentation = Phoneme Segmentation. Each subtest had 12 items with the exception of the letter sound knowledge subtest which had 32 items. Mean raw scores are reported.

** $p<0.05$.

2.3.3 Correlation analyses

A correlation analysis (Pearson correlation matrix) was undertaken to examine associations between the performance on the experimental tasks and phonological awareness ability as well as other measures of speech and language. The combined raw score from the phonological awareness subtests of the PIPA (excluding letter knowledge) was used to gain an overall measure of phonological awareness development. The PIPA letter knowledge subtest was isolated as a separate task for the correlation analysis. Raw scores from the phonological representation tasks were converted into percentage correct scores for analysis purposes. Results revealed that two of the receptive based phonological representation tasks, PR judgment and NW learning, were moderately correlated with phonological awareness ability ($r = 0.47$ and $r = 0.55$ respectively). Performance on these two tasks showed moderate to high correlation with speech production, receptive vocabulary and letter knowledge measures**.** Performances on the receptive gating task, however, showed little association with other measures employed. The two production-based tasks (real and nonword repetition) were highly correlated with the speech production measure (as expected), but showed little association with performance on phonological awareness, receptive vocabulary or letter knowledge as indicated in Table 4. The speech production measure also showed little association ($r = 0.20$) with phonological awareness performance.

Table 4. *Pearson's r values for correlations between performance on phonological representation, speech and phonological awareness measures*

	Speech	Letter knowledge	Combined PA score	Nonword Repetition (PCC)	Real word repetition (PCC)	Nonword Learning	PR Judgment	Receptive Gating
Receptive Vocabulary	0.32	0.54	0.53	0.20	0.16	0.55	0.52	0.25
Speech (PCC)	-	0.10	0.20	****0.94	****0.97	*0.57	*0.57	0.01
Letter knowledge	-	-	****0.87	0.14	0.12	0.43	**0.58	0.31
Combined PA score	-	-	-	0.25	0.26	0.55	0.47	0.27
Nonword Repetition (PCC)	-	-	-	-	****0.93	0.49	0.56	0.18
Real-word Repetition (PCC)	-	-	-	-	-	**0.60	0.55	0.11
Nonword Learning	-	-	-	-	-	-	***0.67	0.20
PR Judgment	-	-	-	-	-	-	-	0.30

*$p = 0.05$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$

2.4 Discussion

This study examined the performance of preschool children with moderate to severe speech impairment on experimental tasks designed to tap underlying phonological representations and a standardised assessment of phonological awareness. Children with speech impairment (mean age = 4:05) were matched with children demonstrating typical speech development (mean age = 4:07) on receptive vocabulary and receptive language measures. The experimental tasks eliminated the use of children's motor-speech system, which have been engaged during previous investigations into phonological representations (Larivee & Catts, 1999; Swan & Goswami, 1997). The first hypothesis stated that children with speech impairment would perform below the level of children with typical speech development on the novel receptive tasks. This hypothesis was supported by the results for two of the three receptive experimental tasks. As a group, children with speech impairments performed significantly below children without speech impairment on the PR judgment and NW learning tasks. To perform well on the PR judgment task, children needed to perceive the spoken word and access an accurate underlying phonological representation of the target word. Children with speech impairment were more likely to make incorrect judgments of the accuracy of stimuli compared to children with typical speech development.

The NW learning task required children to quickly develop a phonological representation for a new word (i.e., nonword) based on six training slides with visual and auditory stimuli. Children were then required to reflect on their newly acquired phonological representation to make judgments on the accuracy of spoken productions of the target nonword. Again, children with speech impairments had more difficulty making judgments on the correctness of target words compared to children with typical speech development. These findings support previous studies that have reported that children's speech impairments may be partly attributable to poor quality underlying phonological representations (Larivee & Catts, 1999; Rvachew et al., 2003; Swan & Goswami, 1997). The results also suggest that children with speech impairments are more likely to have difficulties forming new phonological representations compared to children without speech impairment.

The findings indicated that the PR judgment and NW learning tasks presented were appropriate assessment tasks for this population. The tasks identified differences between the two groups, and performance on these tasks were positively associated with development in other areas known to influence literacy development (i.e., vocabulary and letter knowledge). The results support previous studies that have reported the use of receptive judgment tasks to infer characteristics of underlying phonological representations (Carroll & Snowling, 2004; Nittrouer, 1996; Rvachew et al., 2003).

The results from the receptive gating task indicated it was not a sensitive measure for differences in phonological representations between the two groups. The small correlations between receptive gating task scores and letter-sound and phonological awareness performance do not support the use of this task to examine early skills related to the development of print decoding. This finding contrasts with Metsala's (1997b) report of children's performance on a gating task as predicting reading ability. Metsala's findings, however, were based on a gating paradigm task presented to children aged 6-7 years. The task response criteria required children to say the target word as opposed to the current study's requirement of selecting the target from an array of three items. The stimuli used by Metsala (1997b) also involved the careful selection of *high-* and *low*-use words from *sparse* and *dense* lexical neighbourhoods. The response criteria and stimuli used in the current study's receptive version of the task may have contributed to the insignificant findings. Children were provided with a visual representation of the correct response together with two distracter items, thus reducing the need to perform a wider search and comparison of underlying phonological representations to identify the target word.

The second hypothesis examined the correlation between children's performance on receptive phonological representation tasks and performance on early phonological awareness assessment tasks. Participants' performance on phonological awareness measures provided moderate correlations with performance on the PR judgment and NW learning tasks. These results support previous findings examining the importance of children's underlying phonological representations to the development of phonological awareness (Carroll & Snowling, 2004; Rvachew et al., 2003). The study also identified stronger correlations between performances on phonological awareness tasks and the PR judgment task and NW learning tasks than between the measures of speech production and phonological awareness tasks. This finding suggests that the development of phonological awareness, as measured on the tasks in this study, relies more on an ability to form precise and detailed underlying phonological representations of words, than the accurate production of spoken words. This is consistent with previous findings of similar profiles of phonological awareness weakness in children with speech impairment and children at risk of reading disorder, without any obvious speech impairment (Carroll & Snowling, 2004; Swan & Goswami, 1997). Children who do not have access to precise phonological representations will struggle to consciously consider and manipulate a word's segmental components, as required during phonological awareness tasks (Elbro, 1996). This difficulty is also likely to influence early decoding of printed words with children having difficulty accessing or retrieving speech sound information from underlying phonological representations.

This study found a moderate correlation between receptive vocabulary and performance on the PR judgment (r = .52) and NW learning (r = .55) tasks. This finding provides partial support for a relationship between vocabulary acquisition and development of well-specified phonological representations as proposed by the *lexical restructuring* (Walley, 1993) and *segmentation* (Fowler, 1991) hypotheses. No correlation was observed between word (i.e., both non and real) repetition tasks and receptive vocabulary skills. This does not support Metsala's (1999) report of nonword repetition skill as a function of vocabulary size. The speech impairments of children in this study, however, confound the use of nonword and real word repetition tasks. Although performances on nonword repetition tasks may provide valuable information about a child's phonological perception and production, it has also been argued that these tasks are better described as tests of short-term phonological memory (Gathercole, 1995a; Gathercole & Baddeley, 1997). Poor nonword repetition could be caused by reduced perception, errors in encoding phonological information, storage difficulties, retrieval and motor planning impairments (Edwards & Lahey, 1998; Elbro, 1996; van der Lely & Howard, 1993). Nonword repetition tasks may bypass the need to create an underlying phonological representation when considered within Stackhouse and Wells's (1997) model of speech processing. The model specifies that speech may be produced by moving a phonological plan directly from the phonological recognition component to the motor-programming component of speech processing without a need to involve higher-level phonological representations.

The findings from this study suggest that performance on PR judgment and NW learning tasks may provide useful information on children's ability to create and access underlying phonological presentations. Results from assessments designed to measure phonological representations may contribute to the explanation of why some children fail to make appropriate progress in their phonological awareness and reading development. There is, however, a need to examine children's performance on these and other measures over time, particularly as they enter school and are exposed to formal reading instruction. Comparisons between children's performance on speech, phonological representation, phonological awareness, and early print decoding tasks will provide valuable information on the relationships between phonological representations and the development of speech and word recognition skills. The following chapter details a prospective longitudinal study that investigated these relationships.

Chapter 3. A Prospective Longitudinal Study to Examine the Development of Phonological Representations, Speech, Phonological Awareness, and Print Decoding

3.1 Introduction

Without specific intervention targeting phoneme-level awareness, children with speech impairment demonstrate persistent deficits in accessing phonemes within words (Gillon, 2002, 2005). Evidence from studies examining children with reading disability suggests that poorly specified phonological information associated with words in long-term memory underlies phonological awareness and reading development problems (Elbro, 1996; Elbro et al., 1998; Fowler, 1991). For example, when confronted with a new or unfamiliar word, a child who has difficulty accessing phoneme-level information is unlikely to be capable of sounding out the target word to access its underlying meaning. Successful performance on phonological awareness tasks such as phoneme segmentation and phoneme blending also requires access to well-specified and segmental phonological representations. As performance on phonological awareness tasks is the best predictor of long-term reading outcomes (Lundberg et al., 1980), there is a need to investigate whether phonological awareness difficulties experienced by some children with speech impairment are the result of phonological representation deficits. Tracking children's performance on phonological awareness tasks and comparing these results with phonological representation measures will help to clarify the role of phonological representations during early reading development.

This knowledge is essential to develop our understanding of why children with speech impairment are at increased risk of reading disability.

There is also a need to examine the relationship between the emergence of speech skills and the development of phonological representations in young children. Although the acquisition of speech skills varies greatly between children (Dodd, 2005), clinical experience suggests that children exhibiting normal speech development produce near adult-like speech with few speech errors from around 4- to 5-years-of-age. By around age 8, children with typical development are thought to possess phonological representations containing well-specified phoneme-level information (Fowler, 1991). In contrast, preschool children with moderate to severe speech impairment do not achieve normal speech production until an average of 7- to 8-years-of-age (Shriberg, Gruber et al., 1994). Therefore investigation is required to determine if the later appearance of speech skills in children with speech impairment is related to persistently immature phonological representations.

Findings from longitudinal studies have provided a range of speech, phonological awareness, and reading outcomes for children with speech impairment (Bernhardt & Major, 2005; Bird et al., 1995; Hesketh, 2004; Gillon, 2002, 2005; Nathan et al., 2004; Stackhouse, 2000; Webster & Plante, 1992, 1995; Webster et al., 1997). Stackhouse (2000) reported 25% of preschoolers with isolated speech impairment demonstrated delayed reading development at age 6 years and 6 months. A lower incidence rate of 11% was reported by Hesketh (2004) who reassessed a group of preschool children between 6- and 7-years-of-age with moderate to severe speech impairment using speech, phonological awareness, and word recognition measures. Four out of 35 children reassessed scored below -1SD from the group mean on phonological awareness and single word reading measures. One of these children scored below -2SD from the mean. Although these findings supported previous studies that have indicated performance on phonological awareness measures is the best predictor of long-term reading outcomes, several methodological shortcomings require consideration. A further 26 preschool children originally identified with a speech impairment were not included in Hesketh's (2004) reassessment study due to an inability to acquire parental consent. Additionally, no control group was assessed, creating difficulty interpreting the performance of children with preschool speech impairment. Gillon (2002; 2005) demonstrated that improvement in speech production alone may not ensure positive reading outcomes. Rather, children with moderate or severe speech impairment require explicit phonological awareness instruction and an understanding of the relationship between phonemes and graphemes to enhance both reading and spelling development. Although researchers have speculated that developmental changes in underlying phonological representations facilitate the development of phonological awareness (Elbro, 1996; Fowler, 1991; Walley, 1993), research is required to examine the nature of this relationship in children with speech impairment.

Large differences between children with and without speech impairment were evident on the real and nonword repetition measures described in chapter 2. Effective performance on these repetition tasks requires robust speech input and output systems (van der Lely & Howard, 1993; Adams & Gathercole, 2000). Children with weak speech output systems, therefore, will struggle to produce accurate responses, even if their auditory input system is capable of supporting the development of accurate phonological representations. Nevertheless, as children's speech accuracy improves these production-based tasks will provide valuable information to compare with performance on receptive tasks designed to examine underlying phonological representations. This will also help to determine how improvements in speech production are related to or influenced by changes in phonological representations over a period of time.

Studies utilising speech perception-based judgment tasks have reported a relationship between persistent speech impairment and poor reading development (Bird et al., 1995; Nathan et al., 2004). Using a longitudinal study design, Nathan et al. (2004) reported children with persistent speech impairment at age 7 were more likely to experience reading difficulties.

A group of children with speech and language impairment, a group with speech impairment only, and a control group were compared on measures of speech, phonological processing, and word recognition development. Of particular interest to the current study, is the lack of significant findings between children with and without speech impairment on the *input phonology* tasks reported. Four input tasks were presented to the children over the course of the study. A same-different task required children to match or differentiate pairs of real and nonword stimuli. Two judgment tasks required children to indicate whether a spoken word matched a corresponding picture. The fourth task was a nonword matching task that required children to match two out of three spoken nonwords. The cognitive processing required in each of these tasks is likely to either involve (real words) or simulate (nonwords) reference to underlying phonological representations (Nathan et al., 2004). Scores from the four separate auditory discrimination tasks were combined and converted to standard scores for data analyses. The only significant difference in performance on these measures was observed between children with speech and language impairments and both the control and speech impairment groups at age 5:8. The data reduction procedures undertaken by the researchers, however, may have obscured further group differences, with at least 80% of the variance in input phonology scores unaccounted for by the factor loadings at each assessment trial (Nathan et al., 2004). Therefore, further investigation into the use of these types of tasks to determine differences between children with and without speech impairment is warranted.

The limited range of stimuli used in Nathan et al.'s (2004) input phonology task may also have contributed to insignificant findings. Error stimuli were created by substitution, deletion or transposition of consonant sounds in a variety of real and nonwords (e.g., *elephant* presented as /ælɪfɪnt/ or /æfɪlɪnt/; *plate* presented as /pleit/ or /peit/. Young children's phonological representations may contain enough detail to enable them to discriminate between stimuli with gross manipulation of consonant segments. Yet these children may not have access to the most distinct variants of words that are needed during decoding and spelling tasks (Elbro, 1996). Differences have been observed when children without speech impairment, but at risk of reading disability, are required to provide accurate pronunciations of vowel sounds within multisyllable words (Elbro et al., 1998). Similarly, children who have difficulty judging the accuracy of spoken words with fine-grained changes made to vowel sounds may possess poorly specified phonological representations (Sutherland & Gillon, 2005).

The use of two novel receptive assessment tasks to investigate underlying phonological representations in young children with speech impairment was supported by evidence presented in chapter two. As a group, children with speech impairment performed poorly on a task requiring judgments on the pronunciation of multisyllable words, compared to children with typical speech development. These children also had greater difficulty developing phonological representations for nonwords, and then reflecting on these during a judgment task. The cross-sectional study design reported in chapter two can provide valuable information on children's abilities, however, it has limited value in describing developmental relationships such as how improvement in speech production over time may be reflected in changes in underlying phonological representations. This chapter reports a prospective longitudinal study designed to examine phonological representations and the relationship with speech, phonological awareness, and print decoding development in children with speech impairment. To achieve this, the study compared the performance of children with and without speech impairment on speech and receptive phonological representation tasks as well as measures of phonological awareness and early print decoding. The specific research questions examined were –

1. Do children with speech impairment demonstrate consistently poor performance on receptive tasks designed to examine phonological representations compared to children without speech impairment?

2. Do children with speech impairment vary across time on performance on speech production measures at each assessment trial?
3. Do children with speech impairment demonstrate consistently lower performances on phonological awareness measures examining phoneme-level awareness and early print decoding ability, compared to children with typical speech development?
4. Does performance on phonological representation measures continue to correlate with performance on speech measures as children's speech improves?
5. Do children's performances on phonological awareness measures and early print decoding correlate with performance on phonological representation tasks, as children encounter formal reading instruction at school?

The hypotheses examined for each research question were -

1. Children with speech impairment will perform poorly on phonological representation tasks at each assessment trial compared to children with typical speech development;
2. Considerable variation will be evident in the speech production ability of children with speech impairment at each assessment trial;
3. Phonological awareness tasks that tap phoneme-level abilities and early print decoding measures presented at trial 3 and 4 will be more challenging for children with speech impairment than children with typical speech development;
4. As the speech production skills of children with and without speech impairment increase across assessment trials, correlation coefficients between speech production and performance on phonological representation tasks will decrease;
5. Children's performance on phonological awareness and early print decoding measures will correlate with receptive phonological representation task scores at each assessment trial.

3.2 Method

A prospective longitudinal study design was employed to investigate the research hypotheses. Participants were assessed at six-monthly intervals over a period of 18 months (trial 1, trial 2, trial 3, and trial 4). Results from trial 1 were reported in chapter 2 above.

3.2.1 Participants

All nine children (1 girl and 8 boys) in the speech impairment (SI) group and 17 children (7 girls and 10 boys) from the typical speech development (TS) group described in chapter 2, participated in each reassessment trial. At each trial, a petrol voucher valued at ten dollars was provided to parents as a contribution to travel costs incurred when attending sessions. Table 5 provides a summary of group age and speech characteristics at each trial. Receptive vocabulary and receptive language performance measured at trial 1 are reported in Table 1 above.

Table 5. *Mean participant ages and PCC scores at each assessment trial*

	SI Group		TS Group			
	M	SD	M	SD	P value	Cohen's *d*
Age (months)						
- Trial 1	53.33	6.50	55.88	2.39	0.1566	0.521
- Trial 2	58.78	6.76	61.88	3.02	0.1164	0.592
- Trial 3	64.11	6.95	67.29	2.80	0.1078	0.600
- Trial 4	69.56	5.73	71.76	2.49	0.1820	0.498
PCC – Total						
- Trial 1	38.89	12.00	90.94	7.68	<0.0001	5.167
- Trial 2	62.22	21.79	94.47	5.09	<0.0001	2.038
- Trial 3	72.78	23.08	96.65	2.60	0.0003*	1.453
- Trial 4	78.11	21.09	97.47	1.91	0.0011*	1.293

Note. SI group = Speech impairment Group, TS group = Typical speech development group, PCC = Percent consonants correct.

*$p<0.001$

3.2.2 Procedures

At each trial, participants were presented with assessment measures that examined speech production, phonological representations, and phonological awareness. Early print decoding skills were assessed at trial 3 and 4, and isolated word recognition ability was examined at trial 4. The examiner presented assessments in a quiet university clinic facility. All assessment sessions were video and audio taped for reliability and scoring purposes. Details of the assessment tasks are provided below.

3.2.2.1 Phonological representation tasks

Separate versions of the phonological representation judgment (PR judgment) and nonword learning (NW learning) task were developed for each trial. All stimuli were developed using the procedures set out in chapter 2 above. Items for each version of the experimental tasks were verified by presenting each item to ten adult listeners to ensure that speech stimuli were perceived as anticipated (i.e., as either correct or incorrect production of target words and nonwords). Several items were discarded after adults could not agree on the correctness of the production. The receptive gating task presented at trial 1 was not used in subsequent trials, as results indicated it was not sensitive to possible phonological representation deficits.

Participants were familiarised with the picture stimuli used on the PR judgment task by asking children to name the pictures at least 15 minutes prior to presentation of the task. If a child was unable to name a picture, prompts were provided to direct the child to the target word. A model was provided if children were unable to name the target picture after prompting. Participants' responses on the PR judgment and NW learning task were scored as correct or incorrect.

3.2.2.1.1 PR judgment task

As several participants performed near ceiling at trial 1, the stimuli used on subsequent versions of the PR judgment task were changed to incorporate different and more challenging stimuli. This is consistent with previous reports of new stimuli being presented to prevent children's performance reaching ceiling when examining developmental phonological knowledge (e.g., Lonigan et al., 2000). The underlying skills required to succeed on the task at each trial remained constant with stimulus words presented either being correctly pronounced or containing fine-grained alterations to stressed or unstressed vowel sounds. For example, the word *monster* was pronounced incorrectly as /mounstə/ at trial 2 and /mʌnstə/ at trial 3. The PR judgment task presented at trial 2, 3, and 4 consisted of 30 slides (5 practice items and 25 test items) with a picture of the target word, a green tick and a red cross. Participants were seated in front of the computer, and wore stereo headphones (Sony MDR-V300) connected to the computer, during task presentation. Children were asked to decide if words were spoken in a *good* or *not a good* way. Instructions were also provided for children to indicate a correct production by pointing to the green tick. To indicate an incorrect judgment, children were asked to point to the red cross. Errors made on practice items were corrected with verbal feedback.

3.2.2.1.2 NW learning task

The NW learning task was also developed using Powerpoint® slide presentations. Each version of the task consisted of separate learning and judgment components. The learning component required children to observe picture slides and simultaneously listen to a prerecording of the pictured object's *nonword* name or a short phrase containing the target nonword. As the use of stimuli from previous trials could involve recollection of prior phonological knowledge, new nonword stimuli were utilised on each version of the task. This ensured that stimuli were true nonwords. The number of slides providing learning opportunities for each nonword were decreased from 6 (trial 1), to 5 (trial 2) and then 4 (trial 3 and 4). The rationale for reducing the exposure to the nonword and therefore limiting learning opportunities was to increase or maintain the level of difficulty on this task as the children increased in maturity. The increase in task difficulty was also supported by several children with typical speech development performing close to ceiling at each trial.

The second component of the task required children to listen to and indicate their judgment of recorded stimuli. The judgment stimuli were either the correct nonword presented during the learning slides or a mispronounced version of the target nonword. Children were required to point to either a green tick or a red cross depending on their perception of the stimuli as either *good* or *not a good* way of saying the target nonword. A training item comprising of both learning and judgment slides was the first item presented for each version of the task. Corrective feedback was provided on both learning and judgment slides for the training item. Children were then presented with 20 test items that consisted of a set of learning slides and four judgment slides. An example of a nonword presented at trial 2 is /trɒknifaiʃ/. Mispronounced variations of the nonword presented included /trɒknifeiʃ/ and /trʌknifaiʃ/. A full list of stimuli and task instructions presented to children is provided in Appendix B.

3.2.2.2 Test item and scoring reliability

Responses to the items on both the PR judgment and NW learning tasks were analysed to determine the reliability of test items used. As these tasks were experimental in nature, all correct and incorrect responses across the four presentations were combined in a classical item analysis. Internal consistency reliability for the PR judgment task yielded a coefficient alpha = 0.844 which met the most rigorous measure of internal consistency (i.e., $a = 0.8$; Nunally, 1978). All NW learning task items combined to produce an acceptable coefficient alpha ($a = 0.794$).

Participant responses were verified using the procedures set out in chapter 2 with an independent examiner reviewing videotapes of four participants (two children randomly selected from each group). No differences were noted between the independent examiner's scores and original scores recorded on tasks at each trial.

3.2.2.3 Speech assessment

Speech measures taken at trial 1 were repeated at each reassessment trial. These assessments were the Goldman-Fristoe Test of Articulation (GFTA) (Goldman & Fristoe, 1986) and the 25 words from the inconsistency assessment subtest of the Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al., 2002). The word familiarity training undertaken at trial 1 was not repeated at subsequent trials. If children were unable to spontaneously name the correct target word, delayed modelling techniques were used to stimulate responses. All responses were transcribed using a broad phonetic transcription and analysed using the *Computerized Profiling* (*CP*) software (Long, Fey & Channell, 2004). The reliability of transcriptions was verified using the process described in chapter 2. The average level of disagreement between examiners ranged from 92% at trial 1 to 97% at trial 4.

The inconsistency of children's speech production was measured using the 25 words from the inconsistency assessment subtest of the DEAP (Dodd et al., 2002). As specified in the DEAP guidelines, words were presented on 3 occasions in the same assessment session, separated by at least 15 minutes. This consistency measure was applied to all children in the SI group at trial 1. At subsequent trials, the measure was only presented to children who recorded greater than 25% inconsistency at the previous trial.

3.2.2.4 Real and nonword repetition task

To examine children's phonological processing of multisyllable real and nonwords, the word repetition tasks presented at trial 1 were presented at each subsequent trial. The same set of 10 real words and a different set of 10 nonwords were used at each trial. The recording, transcription, and verification procedures used for these tasks were the same as used for the speech assessment measures. Both sets of stimuli were developed to ensure that a wide range of speech sounds were covered. Refer to Appendix D for a full list of stimuli presented.

3.2.2.5 Phonological awareness

The Preschool and Primary Inventory of Phonological Awareness (PIPA; Dodd et al., 2000) administered at trial 1 was also presented at trial 2. As the only significant group difference on PIPA subtests was observed on the phoneme segmentation subtest at trial 1, this subtest was also presented at trial 3 and 4. This was also consistent with the study's aim of examining children's ability to access and manipulate phoneme-level information. The letter-sound knowledge subtest of the PIPA was also administered at each trial to provide a measure of children's early print decoding skills. The administration and scoring procedures outlined in the test manual were followed during presentation of the subtests.

A series of Phonological Awareness Probe tasks were presented at trial 2, 3, and 4 to provide information on children's ability to reflect on and work with phonemes. These tasks were originally developed by Stahl and Murray (1994) to examine the influence of task differences and linguistic complexity on phonological awareness skills of kindergarten and first-grade children. The four subtests examined: (a) phoneme blending, (b) phoneme isolation, (c) phoneme segmentation, and (d) phoneme deletion. Findings from Stahl and Murray (1994) supported the use of the tasks with young children. A factor analysis of the four tasks revealed 72.6% of the variance was accounted for by a single factor (eigenvalue = 3.32). Full details of each task and stimuli used are provided in Appendix E.

3.2.2.6 Nonword reading

A nonword reading task was presented to participants at trial 3 and 4 to examine the development of participants' print decoding skills. Nonwords were presented using a Powerpoint® slideshow on a notebook computer. Each word was placed on a single slide for presentation. This task was discontinued if a child failed to respond to 5 consecutive nonwords. Three sets of 10 nonwords of increasing difficulty were presented and are detailed in Appendix F. Responses were scored as correct if the child produced all consonant and vowel phonemes as expected. A phoneme-level score was also calculated based on the total number of graphemes correctly converted into corresponding phonemes by each child. For example, a child reading the nonword *vab* as /væp/ would score 2 out of 3 phonemes correct.

3.2.2.7 Word recognition

Children's early word recognition skills were assessed at trial 4 using the Burt Word Reading Test (Gilmore, Croft, & Reid, 1981). This assessment required children to read isolated words from a single printed page. The easiest words were presented first, with an increasing level of difficulty. The test was discontinued if children incorrectly read or offered no response to 10 consecutive items. The number of words read correctly was recorded and used for analysis.

3.2.2.8 Intervention

All children in the speech impairment group received intervention to improve their speech intelligibility. Intervention, however, was not included as a controlled variable within the study. The intensity of intervention varied between children. A minimum of 6 hours and a maximum of 20 hours direct one-to-one therapy were reported by speech-language therapists. The mean number of intervention hours received by children was 13.5 hours (SD = 3.5). Intervention followed linguistic approaches to reduce the occurrence of speech error patterns. The specific approaches reported, included the Cycles approach (Hodson & Paden, 1991), minimal pair, and traditional methods. Three speech-language therapists also reported that indirect work on developing early phonological awareness skills was included in sessions. The intensity and content of phonological awareness activities, however, was not monitored.

3.3 Results

3.3.1 Phonological representations

3.3.1.1 PR judgment tasks

Children's performances on the PR judgment tasks were examined to determine the extent of group differences and changes in group performances at each trial. A repeated measures analysis of variance revealed significant group [$F(4,21) = 4.11$, $p<0.05$] and time [$F(3,22) = 4.92$, $p<0.01$] effects. No significant group by time [$F(3,22) = 0.46$, $p = 0.63$] interaction was observed. A comparison of group mean scores from the PR judgment and NW learning tasks are provided in Table 6. Cohen's *d* effect sizes were large for group differences at each trial.

3.3.1.2 NW learning tasks

Children's performances on the NW learning tasks were analysed to determine differences between groups at each assessment. A repeated measures analysis of variance using the total percent of items judged correctly, revealed that the group effect narrowly failed to reach statistical significance [$F(4,21) = 2.37$, $p = 0.08$]. However, large effect size estimates (Cohen's $d = 0.834$ to 1.046) were observed at each trial. Additional univariate analyses were undertaken to examine the significance of group differences observed at each trial. The differences were significant at trial 1 [$F(1,24) = 5.29$, $p < 0.05$], 2 [$F(1,24) = 6.66$, $p < 0.05$] and 4 [$F(1,24) = 4.45$, $p < 0.05$]. The group difference at trial 3 was close to significance [$F(1,24) = 3.99$, $p = 0.057$].

Table 6. *Group performances on the PR judgment and NW learning tasks*

	SI Group		TS Group			
	M	SD	M	SD	P value	Cohen's *d*
PR Judgment						
- Trial 1	60.00	21.41	77.45	14.36	0.020*	0.957
- Trial 2	68.00	11.83	81.41	11.04	<0.01	1.172
- Trial 3	76.00	9.80	86.35	6.49	<0.01	1.245
- Trial 4	76.44	13.48	89.41	8.71	<0.01	1.143
NW learning						
- Trial 1	64.71	20.38	78.55	10.59	0.030*	0.852
- Trial 2	60.56	15.30	75.88	13.95	0.016*	1.046
- Trial 3	58.33	12.75	69.41	13.79	0.057	0.834
- Trial 4	68.52	7.86	76.47	9.73	0.046*	0.899

Note. SI group = Speech impairment group, TS group = Typical speech development group. Total percent correct scores are reported.

*$p<0.05$

3.3.2 Speech

Speech production data from the single word elicitation tasks were analysed to examine group differences in speech sound development at each assessment trial. Percent Consonant Correct (PCC) scores (see Figure 4) were submitted to a two-way repeated measures analysis of variance. This revealed a significant group effect [$F(4,21) = 42.49$, $p<0.001$], a significant time effect [$F(3,22) = 32.24$, $p<0.001$], and significant group by time interaction [$F(3,22) = 16.31$, $p<0.001$]. The PCC scores calculated from the real and nonword repetition tasks at each assessment trial were also analysed. Two-way repeated measures analyses of variance revealed significant group effects for both the real word [$F(4,21) = 34.20$, $p<0.001$] and nonword [$F(4,21) = 39.90$, $p<0.001$] repetition tasks. Significant time effects were also observed on both tasks; $F(3,22) = 28.00$, $p<0.001$ (real word repetition), and; $F(3,22) = 10.11$, $p<0.001$ (nonword repetition). Group by time interactions also reached significance for both tasks; $F(3,22) = 10.64$, $p<0.001$ (real word repetition), and; $F(3,22) = 4.99$, $p<0.01$ (nonword repetition).

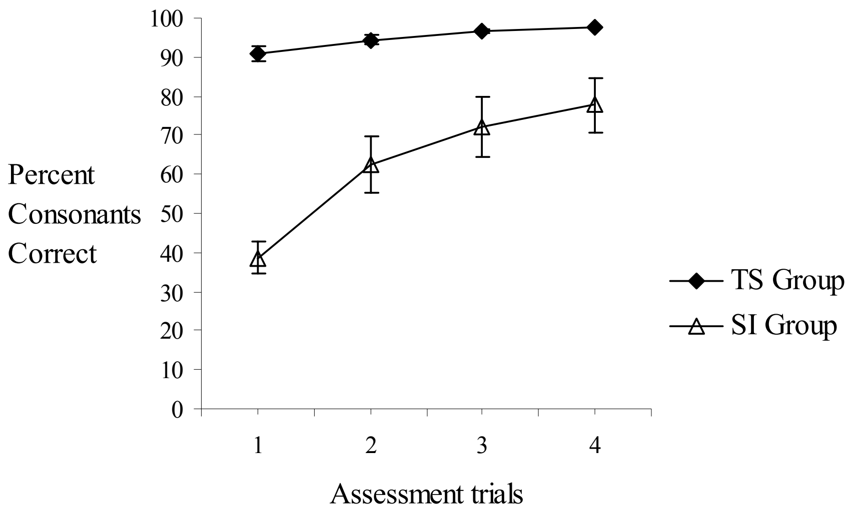

Figure 4. Comparison of group PCC scores at each trial. The average age (months) of all children at each trial were 55 (trial 1); 61 (trial 2); 66 (trial 3); and, 71 (trial 4). PCC scores were calculated using the single word elicitation component of the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986) and 25 words from the inconsistency subtest from the DEAP (Dodd et al., 2002).

The speech output of children in the SI group were analysed to examine characteristics of the group's speech development. A detailed summary of individual speech characteristics including PCC, percent of vowel sounds correct (PVC), levels of use of common speech error patterns as well as substitution and omissions error ratios is provided in Table 7. The table highlights that although group heterogeneity was controlled for at trial 1, children with speech impairment improved at different rates across the study. The variability in progress in speech development is illustrated by contrasting the performance of case number 2 (pseudonym

Henry), whose PCC score improved from 17% at trial 1 to 35% at trial 4, with case 5 (Michael) who increased his PCC from 33% at trial 1 to 99% at trial 4. Only two children (Henry and Richard) continued to meet the severe impairment criteria (Shriberg & Kwiatkowski, 1994) at trial 4. Similarly, these 2 children also recorded PVC scores below 90% at trial 4. The PCC scores of the remaining 7 children ranged from 83% to 98% at the final study assessment. Highly accurate productions of vowel sounds in the range of 98-100% correct were also noted for these 7 children at trial 4. Although significant within group differences continued at trial 4, seven of the 9 children had made considerable progress towards resolving their speech production errors at an average age of 5 years and 10 months.

Table 7. *Speech characteristics of children with speech impairment at each trial*

	Children's Pseudonym, Identification Number and Results at Trial 1, 2, 3, and 4.								
	Meg - 1	Henry - 2	Will - 3	Bryn - 4	Michael - 5	Matthew - 6	John - 7	Zack - 8	Richard - 9
PCC	33-48-59-84	17-25-33-35	58-75-89-89	29-54-71-83	33-95-99-98	47-73-91-91	52-75-83-85	45-77-85-85	33-40-39-50
PVC	71-90-92-98	50-71-77-77	96-95-100-100	69-84-99-98	81-100-100-99	91-98-100-100	89-98-100-99	92-94-99-100	76-87-92-88
NWR	20-46-44-54	28-22-24-25	37-52-80-61	25-48-48-51	40-83-88-83	56-63-70-62	58-61-79-52	41-72-86-72	33-32-45-39
RWR	46-49-60-76	19-24-26-28	43-78-87-82	33-48-62-76	30-93-93-96	42-62-76-78	56-80-76-74	50-82-87-89	29-23-51-57
VF	64-71-50-	37-46-52-48	42-33-7-7	7-11-	50-	35-26-	25–13-	89-37-21-18	71-40-70-68
ES	30-15-	-	28-	15-	-	20-	-	58-	-
FCD	-	98-95-20-17	13-10-	28-	86-	-	-	-	13 -
CR	55-64-	47-69-90-77	23-20-12-9	67-52-18-16	75-	79-35-	66-22-	71-22-	18-52-74-16
LS	37-37-32-32	17-28-50-29	-	53-58-69-33	18-	60-77-	77-83-64-55	80-50-42-37	37-53-69-72
PF	27-40-47-53	-20-57-27	60-	7-53-80-	-	23-40-	23-	20-	33-33-57-53
LSt	31-28-25-16	19-22-9-	23-	- -19-	-	27- - 9	12-	69-	-
FS	50-63-75-25	-38-75-50	57-50-88-88	13-63-75-75	33-	71-63-75-75	88-88-75-88	33- 88 - 75	63-50-50-88
Subs	61-66-83-97	27-37-61-65	90-92-83-88	73-75-95-82	35-100-100-60	66-98-94-84	64-80-97-93	96-98-97-93	62-67-72-77
Omns	38-33-17-3	73-63-39-35	10-8-17-12	27-25-5-18	65-0-0-40	34-2-6-16	36-20-3-7	4 – 2 – 3 - 7	38-33-28-23
Id. Errors	9-7-7-2	9-11-11-18	14-9-2-3	21-10-5-4	8-2-0-0	9-3-1-0	3-0-2-0	4 – 5 – 0 - 0	7-6-6-7

Note. All figures are percentages. Error pattern usage below 5% is not reported. Dashes indicate error pattern no longer used or below 5%. PCC = percent consonants correct; PVC = percent vowels correct; VF = velar fronting (e.g., /k/ → /t/); ES = early stopping (e.g., /s/ → /t/); FCD = final consonant deletion (e.g., /sʌn/ → /sʌ/); CR = cluster reduction (e.g., /bl/ → /b/); LS = liquid simplification (e.g., /r/ → /w/); PF = palatal fronting (e.g., /ʃ/ → /s/); LSt = later stopping (e.g., /tʃ/ → /t/); FS = fricative simplification (e.g., /θ/ → /f/); Subs = substitution errors; Omns = omission errors; Id. Errors = Idiosyncratic Errors. All children's names have been replaced with pseudonyms.

All children in the SI group demonstrated the use of common speech error patterns at trial 1. The most commonly observed errors were velar fronting, cluster reduction, liquid, and fricative simplification. The use of these error patterns tended to decrease over the course of the study. In several cases, however, increases in error pattern use were observed. These increases can be accounted for by changes in the use of substitution and omission errors. For example, Meg's use of the palatal fronting process increased from 27% at trial 1 to 53% at trial 4. Over the same period, her level of omission errors reduced from 38% of errors to 3%, creating the opportunity for greater use of substitution errors. Omission errors accounted for at least 20% of speech errors at trial 1 for 7 of the 9 children (range 27% to 73%). Only Zack produced more than 90% of errors as substitution errors at trial 1. Across the study, children demonstrated an increasing tendency for the use of substitution errors. Although, as the number of errors decreased across the study, several of the substitution and omission percentages appeared unusually large. For example, the 40% omission error use noted for Michael at trial 4 was based on the omission of 2 cluster elements from a total of 5 speech errors.

The use of at least 1 idiosyncratic speech error pattern was demonstrated by all children in the SI group during the study. Only two children failed to reduce their use of idiosyncratic speech errors between trial 1 and 4, with Henry increasing his use from 9% to 18% of all errors. Again, this can be accounted for by his increasing use of substitution errors due to the suppression of sound omission errors. Samples and descriptions of the unusual speech error patterns observed from each child at trial 1 and 4 are provided in Table 8. At trial 1, most children deleted a range of speech sounds. By trial 4, only 3 children continued to delete sounds. Three children produced no unusual speech errors at trial 4. Additionally, the example substitution errors provided in Table 8 were not used at every possible opportunity. This highlighted a degree of inconsistency observed in the speech of several children in the SI group.

Table 8. *Examples of children's idiosyncratic speech errors at trial 1 and 4*

Child	Trial	Error patterns
Meg	1	Glottal substitution, medial liquid deletion (e.g., carrot → /daɪt/), cluster deletion, initial /p/ and /f/ → /d/, medial /n/ → /s/.
	4	Initial /p/ → /d/, medial /k/ → /p/, final /dʒ/ → /ds/.
Henry	1	Initial and medial liquid deletion, deletion of stops, fricatives, affricates, glides, nasals, clusters, initial /r/ → /v/, /j/ → /f/, /f/ → /d/, medial /f/ → /dʒ/, /r/ → /t/.
	4	Deletion of liquids, fricatives, nasal clusters, initial /m/ → /v/, /j/ → /tʃ/, medial /g/ → /z/, /p/ → /t/, final /k/ → /tʃ/, /ŋ/ → /m/, /f/ → /t/.
Will	1	Glottal substitution (e.g., /k/ → /ʔ/), /fl/ → /tl/, /sl/ → /bl/, /dʒ/ → /s/.
	4	/k/ → /kl/, /k/ → /b/.
Bryn	1	Deletion of stops, fricatives, affricates, glides, nasals, clusters, /g/ → /tʃ/, /d/ → /tʃ/, /k/ → /tʃ/, /t/ → /fw/.
	4	/d/ → /dʒ/, /n/ → /m/.
Michael	1	Deletion of stops, fricatives, affricates, nasals, clusters, initial /b/ → /f/, /s/ → /dʒ/, /g/ → /dʒ/.
	4	-
Matthew	1	Deletion of glides, initial /m/ → /w/, /n/ → /w/, /z/ → /r/.
	4	-
John	1	Initial /s/ → /f/, /ʃ/ → /n/, /tʃ/ → /w/.
	4	-
Zack	1	Deletion of fricatives, initial and final /θ/ → /b/.
	4	-
Richard	1	Deletion of 's', 'l' and nasal clusters, initial /tʃ/ → /j/, /dʒ/ → /j/.
	4	Deletion of 'r' and 'l' clusters, initial /tʃ/ → /s/ & /z/, /dʒ/ → /s/.

Four children with speech impairment recorded an inconsistency score of 40% or above at trial 1. Of these, only Henry continued to demonstrate highly inconsistent speech across the study. Richard (child 9) demonstrated the second highest level of inconsistency with 32-40% of words produced inconsistently at each assessment trial. An in-depth analysis of a child with inconsistent speech production and consideration of the relationship between inconsistent speech production and underlying phonological representations is presented in chapter 5.

3.3.3 Phonological awareness

Scores from the PIPA subtest and phonological awareness probes were analysed to determine the extent of group differences at each assessment trial. The combined PIPA subtest scores (as described in chapter two and excluding the letter-sound knowledge subtest) obtained at trial 1 and 2 were submitted to a repeated measure ANOVA. No significant group differences were observed on the combined PIPA subtest scores [$F(2,23) = 0.46$, $p = 0.63$]. As the combined PIPA subtest scores included measures of syllable, rime and phoneme-level phonological awareness, individual subtest scores were also submitted to repeated measures ANOVAs to determine the significance of group differences. The only subtest to provide a significant group difference was the phoneme segmentation subtest which was administered at all 4 assessment trials [$F(4,21) = 3.766$, $p = 0.02$]. Closer inspection of individual performances on PIPA subtests at trial 2 revealed that 1 child with speech impairment and 1 child with typical speech development were considered at risk with scores below one standard deviation of the mean for the same age level on at least two subtests. These findings provided further support for the specific examination of phoneme-level phonological awareness skills. A comparison of group performance on combined PIPA subtest and PA probe scores is provided in Figure 5.

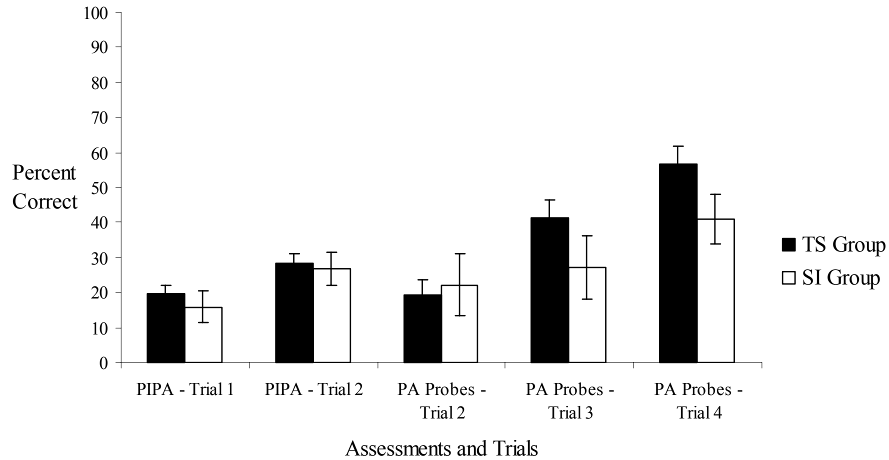

Figure 5. Group performances on phonological awareness tasks at each trial. The mean percent correct for combined PIPA subtests and PA probes are reported. All PIPA subtests were presented at trial 1 and 2. PA probes were presented at trial 2, 3, and 4.

The combined scores from the experimental phonological awareness probes were analysed to determine group differences in manipulating words' phoneme-level details. A repeated measures ANOVA revealed a significant group [$F(3,22) = 5.43$, $p<0.01$], time [$F(2,23) = 78.34$, $p<0.0001$], and group by time [$F(2,23) = 8.29$, $p<0.01$] effects. Separate repeated measures analyses of PA probe subtest scores were undertaken to investigate which subtest performances provided group differences. The phoneme blending subtest results provided significant group [$F(3,22) = 4.16$, $p<0.05$], time [$F(2,23) = 13.34$, $p<0.001$], and group by time [$F(2,23) = 5.26$, $p<0.05$] effects. Scores from the phoneme identity subtest also provided significant effects for group [$F(3,22) = 4.06$, $p<0.05$], time [$F(2,23) = 17.24$, $p<0.0001$], and group by time [$F(2,23) = 4.69$, $p<0.05$] analyses. Similarly, analysis of the phoneme segmentation subtest scores revealed significant group [$F(3,22) = 5.54$, $p<0.01$], time [$F(2,23) = 9.51$, $p<0.001$] and group by time [$F(2,23) = 7.87$, $p<0.01$] effects. No significant group differences were observed on the phoneme deletion subtest across the study [$F(3,22) = 1.86$, $p = 0.17$].

Children in the SI group demonstrated considerable within-group variability on the phonological awareness probes tasks presented at trial 2, 3, and 4 (see Figure 6). Seven of the 9 children with speech impairment performed in a band between the mean and -2 SD from the mean of the TS group at trial 3 and 4. Although several children scored zero on measures at trial 2 and 3, all children demonstrated some improvement in phonological awareness skill across trials. Both Michael and Zack performed well above the mean of the TS group at each trial. These two children were the eldest in the group, and had the most exposure to formal literacy instruction.

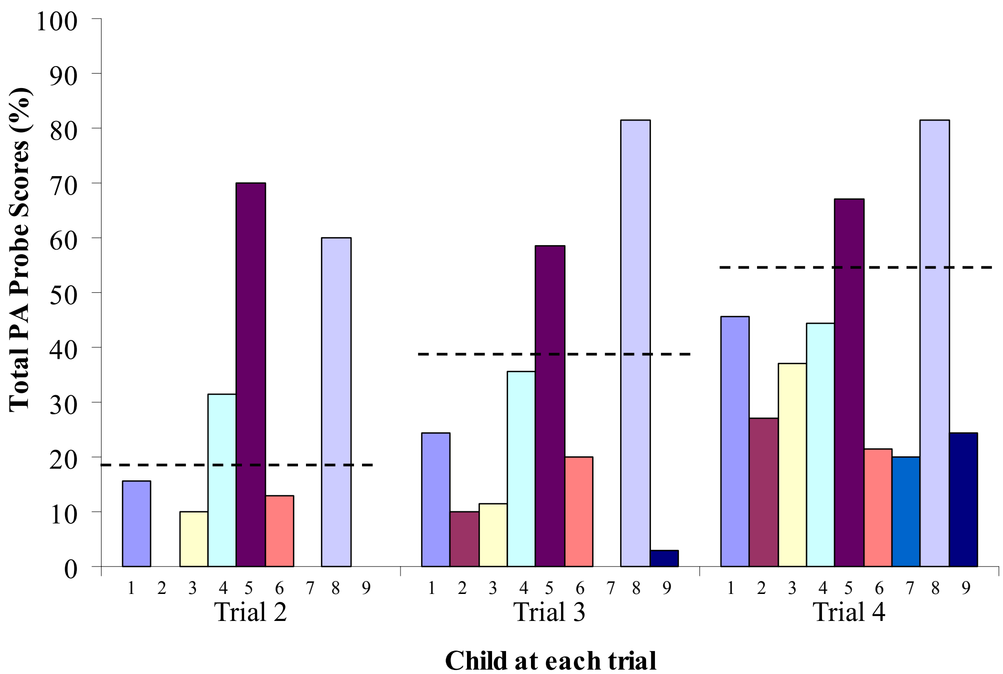

Figure 6. Performances of individual children in the SI group on PA probes. *Note.* The dashed lines represent the mean score of the TS group. No line is shown to represent -2SD as it was located below zero.

3.3.4 Print decoding and word recognition

Scores obtained from the letter-sound knowledge subtest of the PIPA, Burt reading test and nonword reading measure were analysed to investigate group differences in print decoding and word recognition skills. The letter-sound knowledge subtest of the PIPA was presented at each trial. The percent of letter-sounds correctly identified was submitted to a repeated measure ANOVA. No significant group difference was observed [$F(4,21) = 1.87$, $p = 0.15$]. As illustrated in Figure 7, however, group performance diverged at trial 2. To investigate this divergence, separate univariate analyses were performed. These analyses revealed significant group differences at trial 3 [$F(1,24) = 4.41$, $p = 0.047$] and trial 4 [$F(1,24) = 6.02$, $p = 0.02$].

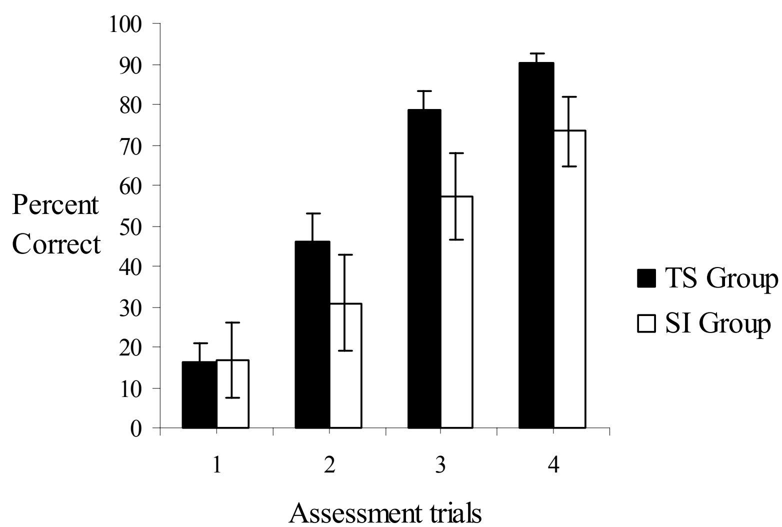

Figure 7. Letter-sound knowledge scores at each trial. The percent of sounds correctly produced for 32 letter or letter combinations are reported.

The total number of words read correctly from the Burt reading test at trial 4 were analysed using a t-test [$t(1,24) = 0.4714$, $p = 0.63$]. The average age of children in the study at the only presentation of the Burt reading test (trial 4) was 5 years and 11 months. Figure 8 illustrates a small group difference with large standard errors. Closer inspection of performances by children in the SI group revealed that Michael and Zack were able to read notably more words than their peers in the SI group and many of the children in the TS group. As shown in Figure 9, two children also performed at the same level as the mean of the TS group and two children were unable to read any words. In contrast, all children in the TS group were able to read some words on this task.

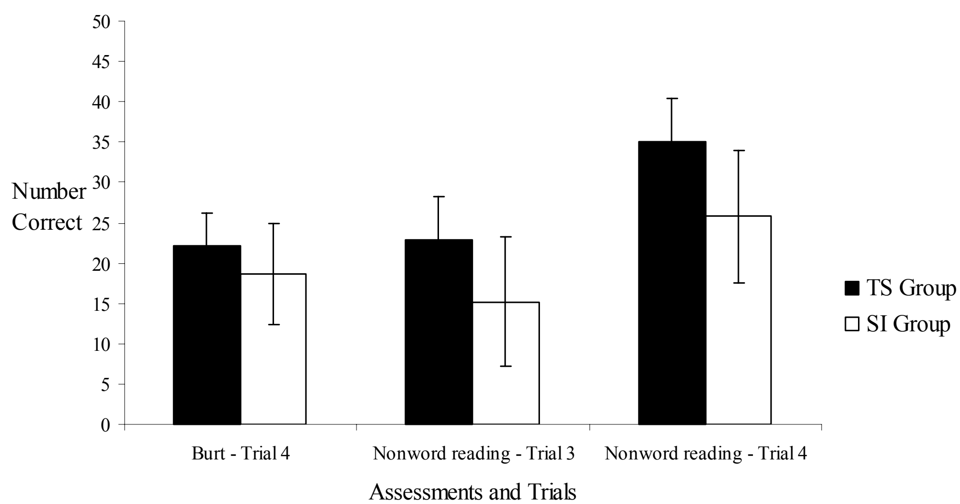

Figure 8. Group performances on Burt word reading test and nonword reading task. Children were aged an average of 66 months (trial 3) and 71 months (trial 4). Figures reported are the total words read correctly for the Burt word reading test and the total number of phonemes read correctly for Nonword reading task.

The number of phonemes read correctly on the nonword reading task presented at trial 3 and 4 was analysed to examine group differences in early print decoding. A repeated measures ANOVA [$F(2,23) = 0.4795$, $p = 0.63$] revealed no significant group differences. A visual inspection of Figure 8 revealed a wide difference between group means and large standard deviations at trial 3 (SI group $M = 15.22$, $SD = 23.84$; TS group $M = 22.94$, $SD = 22.06$). This warranted closer examination of within-group performances. The task involved the presentation of a maximum of 30 nonwords containing 99 phonemes. Inspection of individual data at trial 3 showed 3 of the 9 children with speech impairment performed close to or well above the average of the TS group. In contrast, six of the 9 children (66%) in the SI group performed very poorly on this task and could either not convert any graphemes into corresponding phonemes or identified less than 6 initial consonants correctly. This compared to only 4 out of 17 (24%) children in the TS group who performed at this low level.

The disparity in group ability to decode graphemes into phonemes using nonword stimuli continued at trial 4. Forty-four percent ($n = 5$) of the children with speech impairment showed persistent difficulty at trial 4, compared to only 5% ($n = 1$) of children with typical speech development. As shown in Figure 9, six children were unable to decode any complete nonwords correctly at trial 3 and 4. Analysis of phonemes read correctly by children in the SI group revealed that 5 children were unable to read any phonemes at trial 3. One child, Matthew, read 5 phonemes. Two of the 6 children who were unable to read nonwords at trial 4, were unable to read any phonemes. The remaining four children correctly read between 2 and 13 phonemes. Both Zack and Michael also outperformed their peers and many children in the TS group by correctly reading a number of nonwords. The performances of several individual children with speech impairment who demonstrated an inability to decode nonwords are provided in chapter 5.

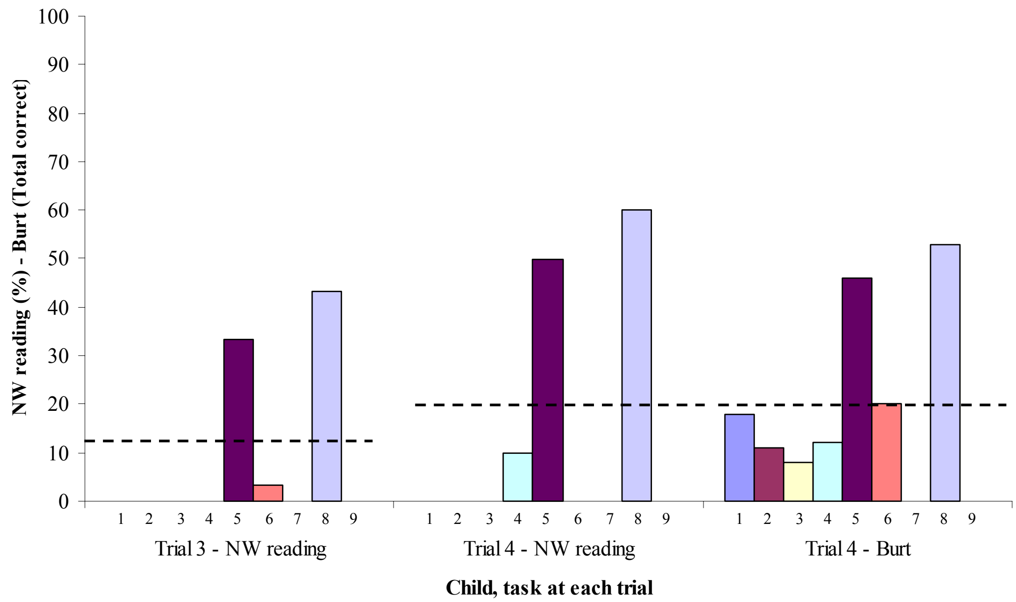

Figure 9. Performances of individual children in the SI group on Nonword reading and Burt word reading tasks compared with mean score of the TS group.

Note. The dashed lines represent the TS group mean.

3.3.5 Correlational analyses

A series of Pearson correlation matrices were created to investigate the relationships between performance on the experimental phonological representation tasks (PR judgment and NW learning) and measures of speech production, phonological awareness and early print decoding. The scores of children in both groups were combined in these analyses. As shown in Table 9, several significant correlations were observed between performance on the PR judgment task at trial 1 and 2 and speech production measures across the study (r = 0.53 to 0.78). Performance on the NW learning task at trial 2 also correlated significantly with trial 4 PCC scores and real word repetition scores at trial 2. A range of moderate correlations were also observed between PR judgment, NW learning, and speech measures at several trials. For example, PR judgment scores at trial 1, 2, and 4 with PCC scores at trial 1.

Table 9. *Pearson's r coefficients for phonological representation tasks with speech production measures*

	PRJ–1	PRJ–2	PRJ-3	PRJ-4	NWL-1	NWL-2	NWL-3	NWL-4
PCC–1	0.57	0.59	0.48	0.53	0.43	0.51	0.43	0.37
PCC-2	**0.73	**0.71	0.49	0.42	0.46	0.60	0.39	0.40
PCC–3	**0.70	**0.73	0.46	0.42	0.42	0.64	0.38	0.38
PCC–4	*0.65	**0.72	0.48	0.47	0.52	*0.66	0.40	0.38
NWRp-1	0.56	0.53	0.39	0.52	0.32	0.40	0.38	0.41
NWRp-2	**0.68	**0.68	0.56	0.49	0.51	0.59	0.43	0.46
NWRp-3	***0.78	**0.68	0.43	0.32	0.49	0.62	0.45	0.35
NWRp-4	***0.74	**0.71	0.59	0.49	0.62	0.71	0.46	0.50
RWRp–1	0.55	0.62	0.48	0.55	0.47	0.52	0.45	0.38
RWRp–2	***0.77	***0.78	0.55	0.34	0.44	*0.66	0.39	0.37
RWRp-3	***0.78	**0.70	0.45	0.38	0.51	0.62	0.41	0.33
RWRp–4	***0.74	*0.66	0.50	0.45	*0.65	0.62	0.45	0.37

Note. PRJ = Phonological representation judgment task; NWL = Nonword learning task; PCC = Percent consonant correct; NWR = Nonword reading; RWR = Real word reading; Numbers 1, 2, 3, and 4 represent the trial number.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Correlations between the experimental phonological representation tasks and phonological awareness measures ranged from low (e.g., $r = 0.01$) to high (e.g., $r = 0.73$). As shown in Table 10, statistically significant correlations were observed between PR judgment task performance at trial 1 and PA probes scores at trial 4 (i.e., $r = 0.66$). Moderate correlations (i.e., $r = 0.61$ and 0.62) were also observed between PR judgment scores at trial 1 and 2 and PA probes scores at trial 2, 3, and 4. Scores from the NW learning task at trial 1 and 2 were also strongly correlated with PA probes results at trial 3 and 4 (i.e., $r = 0.71$ and 0.73).

Pearson's r coefficients for correlations between the experimental phonological representation tasks and early print decoding and word recognition tasks are provided in Table 10. The relationship between scores on the PR judgment task at trial 3 and letter-sound knowledge at trial 4 (i.e., $r = 0.70$) reached statistical significance. Additionally, moderate correlations were evident between the experimental tasks and letter-sound knowledge performance across the study. Performance on the PRJ and NWL tasks at trial 1 and 2 provided moderate correlations with scores on both the Burt word reading (i.e., $r = 0.43$ to 0.56) and Nonword reading tasks (i.e., $r = 0.44$ to 0.52).

Table 10. *Pearson's r coefficients for phonological representation tasks with phonological awareness and print decoding measures*

	PRJ–1	PRJ-2	PRJ–3	PRJ-4	NWL-1	NWL–2	NWL-3	NWL-4
PIPA-1	0.49	0.36	0.32	0.01	0.58	0.38	0.50	0.23
PIPA-2	0.62	0.49	0.40	0.10	0.54	0.59	0.32	0.31
PAP-2	0.48	0.39	0.36	0.08	0.51	0.49	0.31	0.34
PAP-3	0.63	0.52	0.54	0.28	**0.71	0.57	0.50	0.47
PAP-4	*0.66	0.62	0.59	0.33	**0.73	**0.70	0.42	0.48
LK-1	0.58	0.40	0.26	0.11	0.40	0.40	0.28	0.11
LK-2	0.60	0.52	0.40	0.10	0.55	0.64	0.40	0.41
LK-3	0.60	0.52	0.61	0.41	0.63	0.61	0.33	0.42
LK-4	0.49	0.52	**0.70	0.45	0.50	0.60	0.29	0.46
Burt-4	0.51	0.43	0.32	0.15	0.44	0.47	0.23	0.22
NWRead-3	0.56	0.47	0.31	0.10	0.49	0.46	0.35	0.34
NWRead-4	0.56	0.54	0.28	0.04	0.52	0.48	0.33	0.32

Note. PRJ = Phonological representation judgment task; NWL = Nonword learning task; PCC = Percent consonant correct; PIPA = The Preschool and Primary Inventory of Phonological Awareness (PIPA; Dodd et al., 2000); PA Probe = Phonological awareness probes (Stahl & Murray, 1994); LK = Letter-sound knowledge subtest of PIPA; Burt = Burt Word Reading Test (Gilmore et al., 1981); NWRead = Nonword reading. Numbers 1, 2, 3, and 4 represent the trial number.

** $p < 0.01$, * $p < 0.05$

3.4 Discussion

This longitudinal study compared the performance of children with speech impairment to age-matched peers without speech impairment on tasks designed to examine underlying phonological representations, speech production, phonological awareness, and early print decoding skills. The first hypothesis examined was that children with speech impairment would perform consistently below the level of children with typical speech development on the receptive phonological representation tasks at each assessment trial. This hypothesis was supported by the SI group continuing to significantly under perform compared to the control group on the PR judgment task. This finding supports previous research that has found children with speech impairment experiencing greater difficulty reflecting on internal representations of words in order to judge the accuracy of spoken words compared to children without speech impairment (Carroll & Snowling, 2004; Rvachew et al., 2003). These findings are based on the inference that the PR judgment task tapped children's phonological representations. Although the stimuli used in the PR judgment task were changed at each assessment trial, both groups' mean scores increased across trials. This provides some support for children developing more accurate underlying phonological representations as they mature and their speech production improves. Significant group differences were also observed on the NW learning task at 3 of the 4 study trials. This finding implies that children with speech impairment experience greater difficulty developing and reflecting on new phonological representations.

Task presentation variables may have influenced performance on the NW learning task. For example, at trial 3 and 4, children were expected to create new phonological representations based on 4 training slides for each nonword. For some children these new representations may have been weak and susceptible to interference. As no specific control measures were put in place for the presentation order of judgment stimuli, it is possible that presentation of an incorrect production of the target word as the first judgment item may have created interference and affected performance on subsequent items. Further analysis of item responses (e.g., correctly judging mispronounced stimuli) will help to determine specific characteristics of the performance differences between children with and without speech impairment on both the PR judgment and NW learning task. This issue is considered in a detailed analysis of task responses in chapter 4. Assuming, however, that these tasks do involve existing and new phonological representations, children with speech impairment appear to have greater difficulty developing and/ or accessing phonological representations for referencing incoming auditory stimuli.

The second hypothesis tested was that children with speech impairment would demonstrate within-group variation on measures of speech production. This hypothesis was supported by the variable rate of speech development and the range of speech error patterns observed at each trial. The variability in speech improvement was consistent with previous reports from longitudinal studies (e.g., Shriberg, Gruber et al., 1994; Hesketh et al., 2000). This was illustrated by the increasingly greater range of PCC scores observed among the SI group as the study progressed. The range increased from 20% to 58% at trial 1, to between 35% and 98% at trial 4. Although several children were close to achieving near normal speech production by trial 4, most children continued to exhibit some speech difficulties, with two children continuing to present with severe speech impairment. The variable speech outcomes observed at trial 4 demonstrated the persistent nature of speech impairment (Shriberg, Gruber et al., 1994). The level of omission errors observed in the speech of the two children with severe impairment was also consistent with Shriberg, Gruber et al.'s (1994) report that children whose speech is characterised by high levels of omission errors are likely to take longer to achieve speech sound normalisation. These within group differences in types and levels of speech production errors observed across the study further reinforced the variable nature of speech impairment. This finding supports a comparison of performance on phonological representation measures and other study tasks by children exhibiting different speech characteristics. This issue is examined further in chapter 5 through detailed case studies of four children with speech impairment.

Children with speech impairment were hypothesised to experience greater difficulty than children with typical speech development in demonstrating phoneme-level awareness.

Results from the study provided support for this hypothesis. At trial 2, 3, and 4, children were presented with more challenging phoneme-level awareness tasks requiring spontaneous responses. Children with typical speech development consistently outperformed their peers with speech impairment on phoneme isolation, blending, and segmentation tasks. These differences were observed despite large within-group variability among children with speech impairment. This variability was mainly due to the high performance of the two eldest children in the group. These findings support earlier reports of children with isolated speech impairment experiencing difficulties on phonological awareness tasks compared to children without speech impairment (Carroll & Snowling, 2004; Rvachew et al., 2003).

The lack of significant findings on the combined PIPA subtest scores at trial 1 and 2 was at first unexpected. Further consideration of the task requirements, however, may provide explanations for the findings. The subtests examined different levels of phonological awareness. For example, the phoneme segmentation subtest investigated phoneme-level awareness and the syllable segmentation subtest examined syllable level awareness. A significant group difference was also observed on the phoneme segmentation subtest administered at each of the 4 assessment trials, providing further support for the hypothesis that children with speech impairment are more likely to experience difficulty accessing phoneme-level information of words. The insignificant findings on subtests examining syllable and onset-rime awareness indicate that children with speech impairment are as capable as children without speech impairment to reflect on components of words above the level of phonemes.

The third hypothesis also stated that children with speech impairment would demonstrate weaknesses on early print decoding and word recognition measures compared to children without speech impairment. The results provided some support for this hypothesis. The divergence of the letter-sound knowledge observed at trial 2 continued at subsequent trials, indicating that as a group, children with speech impairment were not as adept as their peers with typical speech development, at linking speech sounds with printed letters. Despite the group differences in letter-sound and phoneme-level awareness skills, no significant differences were noted on the real and nonword reading tasks. Although the TS group produced consistently higher mean scores on these assessments, the large standard deviations in both groups' scores precluded significant group differences. Continuing strong performances by two children in the SI group also contributed to an elevated mean score of the SI group and overlaps in group scores.

Individual inspection of the nonword reading data, however, highlighted the majority of children with speech impairment demonstrated an inability to decode unfamiliar written text. The nonword reading task forced children to reference their phonological knowledge to accurately read stimuli, bypassing the possible confounding influence of printed word familiarity. At trial 3, two thirds (n = 6) of the children with speech impairment compared with a quarter of children in the TS group scored zero or well below the average of the TS group, indicating they were unable to or had difficulty converting graphemes into phonemes. Four children with speech impairment continued to be unable to decode any phonemes at trial 4 indicating that some children with speech impairment may experience phonological processing deficits that restrict their ability to decode nonwords. Nonword reading difficulties have also been reported for children with dyslexia (Rack, Snowling, & Olson, 1992; van Ijzendoorn & Bus, 1994), providing support for the possibility of a shared underlying area of deficit with children with speech impairment.

The first of three hypotheses on the relationships between variables stated that the correlation coefficients between the performances of all children in the study on phonological representation tasks and speech measures would decrease as children's speech skills developed. The results supported this hypothesis with significant correlations observed between PCC scores, at trial 2, 3, and 4, and performance on the PR judgment and Nonword learning tasks at trial 1 and 2. These correlations suggest that children's early ability to reflect on underlying phonological representations is related to their ability to accurately produce speech sounds. As expected, correlation coefficients decreased at trial 3 and 4, even though significant group differences were observed on speech and the PR judgment task at these trials. This finding provides some support for children developing more accurate speech production skills, yet continuing to have difficulty reflecting on underlying phonological representations. These correlations support the further refinement of the tasks and their use to investigate the relationship between speech production and phonological representations.

Two further correlational hypotheses were tested to determine if children's performances on the phonological representation tasks would correlate with performance on measures of phonological awareness at each trial and with print decoding performance at trial 3 and 4. The range of moderate to high correlations between scores on the receptive phonological representation tasks, phonological awareness, letter-sound knowledge, and print decoding tasks also provided support for the fifth hypothesis. The coefficients observed provided additional support for a link between underlying phonological representations and emerging phonological awareness and developing print word recognition skills (Carroll & Snowling, 2004; Elbro, 1996; Fowler, 1991; Nathan et al., 2004; Walley, 1993). Before drawing further conclusions on the relationships between variables, the group differences observed requires further investigation. Analyses of item responses are required to identify characteristics that may help develop the validity of the PR judgment and NW learning tasks as appropriate tasks to investigate phonological representations. For example, examining whether or not children with speech impairment experience particular difficulty judging incorrectly pronounced stimuli versus correctly pronounced stimuli will help to determine the characteristics of the phonological representation deficit. The following chapter examines item responses from the experimental tasks and introduces the development of two novel variations of the PR judgment task.

Chapter 4. An Examination of Receptive Phonological Representation Task Variables

4.1 Introduction

The results from the longitudinal study reported in chapter 3 provided evidence for persistent phonological representation deficits in children with speech impairment. Children with speech impairment performed poorly on two receptive tasks designed to examine underlying phonological representations compared to children with typical speech development (TS group). The children with speech impairment (SI group) had greater difficulty determining the correctness of multisyllable words during a phonological representation judgment task and reflecting on the pronunciation of newly learned nonwords. Children in the SI group also performed significantly below children with typical development on tasks examining children's ability to identify and manipulate phonemes within words. The correlations between phonological representation measures and performance on speech production and phonological awareness measures provided evidence for a relationship between these variables. These findings are based on an assumption that the receptive phonological representation tasks required children to access and reflect on their internal phonological representations for words and newly learned nonwords. Further examination of task requirements and item responses is required to provide support for this assumption.

Consideration of the requirements for successful performance on the PR judgment task is needed to determine the influence of variables on children's access to phonological representations. As presented in the longitudinal study, the PR judgment task required children to view a picture, perceive a spoken word, and then access the phonological representation of the target word to determine whether the auditory stimuli was an accurate production of the word depicted by the picture. Pscyholinguistic research has documented the phonological priming effect of picture stimuli during picture naming tasks (Cutting & Ferreira, 1999; Navarrete & Costa, 2005). As presented in the longitudinal study, the provision of picture stimuli on both the PR judgment and NW learning task may have facilitated access to children's phonological representations. After matching incoming auditory stimuli with their own phonological representation, children were required to indicate a correct or incorrect response by pointing to corresponding response item (e.g., a *tick* or *cross*). During many listening-based tasks, such as the phonological awareness measures presented in the longitudinal study, children do not have access to picture stimuli to support access to phonological representations. Carroll and Snowling (2004) identified significant group differences between children with and without speech impairment on a variant of the PR judgment task using live-voice presentation without the support of picture stimuli. Of interest to the current study, is to what degree the provision of picture stimuli facilitated task performance and whether or not the participants benefited from the support provided by accompanying pictures. To investigate the influence of picture stimuli, a novel variation of the PR judgment task was developed.

A second novel variation of the PR judgment task was also developed to investigate the frequency-density effect on the judgment of the pronunciation of words. The frequency-density effect described by Luce, Pisoni, and Goldinger (1990) is the central tenet of the Neighbourhood Activation Model (NAM) of adult spoken word recognition (Luce & Pisoni, 1998). According to Luce (1990), the efficiency of spoken word recognition is influenced by the number of phonetically similar words in long-term memory and how often these words are accessed. Using the gating paradigm, Metsala (1997b) demonstrated that children with reading disability had greater difficulty recognising low-frequency words with few phonologically similar lexical neighbours. Walley (1993) suggested that phonological representations of high-frequency words are likely to become more segmental before words used less frequently. This indicates a potential area of deficit for children with reading difficulties, and is examined further in this study for children known to be at risk of reading disability.

The data from the longitudinal study were analysed further to determine the effectiveness of the receptive phonological representation tasks at identifying children who may have deficits at the level of phonological representations. The group differences observed during the study were based on gross measures of total responses correct (i.e., correct identification of mispronounced and correctly pronounced words). This is consistent with previous studies employing receptive judgment tasks (e.g., Rvachew et al., 2003; Carroll & Snowling, 2004; Sutherland & Gillon, 2005). Reporting of these results appears to include an assumption that inferior performance on tasks such as the PR judgment and NW learning task is due to a reduced ability to detect both mispronounced and correctly produced words. Correctly identifying mispronounced words, however, should be easier for children who possess well-specified phonological representations compared to children with inaccurate or indistinct representations. Conversely, an ability to perceive words pronounced correctly may not necessarily be hampered by poorly specified phonological representations. Further investigation is needed to determine whether children who demonstrate poor performance on phonological representation tasks have difficulty perceiving stimuli pronounced correctly. Failure to perceive correctly pronounced words could be indicative of more general task performance difficulties. In-depth analyses of item responses from both the PR judgment and NW learning task was undertaken to compare children's performance on detecting mispronounced and correctly pronounced words.

The specific hypotheses examined were, compared to children with typical speech development, children with speech impairment would –

1. Demonstrate inferior performance to children without speech impairment on the PR judgment task without supporting picture stimuli. It was also hypothesised that both groups would perform below the level demonstrated on the same task presented with picture stimuli at trial 4;
2. Experience greater difficulty judging low-frequency words from sparse lexical neighbourhoods on the PR judgment task using stimuli based on word frequency and neighbourhood density characteristics; and,
3. Perform poorly on items requiring detection of mispronounced stimuli from the PR judgment and NW learning tasks presented during the longitudinal study. In contrast, it was also hypothesised that children with speech impairment would perform at a similar level to children without speech impairment on PR judgment and NW learning task items requiring judgment of stimuli pronounced correctly.

4.2 Method

4.2.1 Procedures

4.2.1.1 Phonological representation tasks

Two additional versions of the PR judgment task were presented once only at the conclusion of the longitudinal study. These tasks were not described in chapter 3.

4.2.1.1.1 PR judgment task without picture stimuli

The first task variant was created by removing the pictures from the trial 4 version of the PR judgment task. All slides were light green in colour and contained a red tick and green cross for children to indicate their judgments. As slides did not contain pictures to facilitate response tracking, small item numbers were included on each slide to ensure children's responses were matched to the appropriate item. All auditory stimuli presented were identical to those presented on the trial 4 version of the task containing pictures. The procedures followed were the same as other PR judgment tasks described in chapter 3. In addition to the total responses correct score, both the A (i.e., number of accurately pronounced items judged correctly) and B (i.e., number of mispronounced items judged correctly) scores described below were also calculated for each child.

4.2.1.1.2 PR judgment task with frequency – density stimuli

The second revised version of the PR judgment task was developed to investigate the effect of the frequency of use and lexical neighbourhood density characteristics on task performance. Stimuli were selected from target words used in Metsala's (1997b) experiment employing a gating paradigm. Words were selected from Metsala's list based on the ability to represent the word with a picture and familiarity for 6-year-old children. For example, *dog* (see Figure 10) was included and *voice* was not. All words selected were single syllable nouns that Metsala (1997b) classified on two dimensions; density of lexical neighborhood, and frequency of use.

Metsala (1997b) used the following method to determine the allocation of words to the sparse or dense lexical neighbourhood category. Target words were selected from Luce's (1986) database of single syllable words used in speech perception studies with adults. Words were then analysed to determine the number of words that could be generated from it by adding, deleting or substituting a single phoneme within the rime component of the word. Words classified as residing in sparse neighbourhoods had less than 8 lexical neighbours and words from dense neighbourhoods had more than 12 lexical neighbours. For example, the word *dog* was considered to reside in a sparse lexical neighbourhood with neighbours including *dob, dock, don, dot, dug, dig,* and *dag*. Words such as *log* and *fog* were not considered neighbours, as their creation required substitution of the onset phoneme. The word frequency statistics reported by Metsala (1997b) were also replicated. An example of a high-frequency word was *bag* and a low-frequency word was *comb*. Each stimulus was allocated to one of the following categories; 1) high-frequency – dense (n = 5); 2) high-frequency – sparse (n = 8); 3) low-frequency – dense (n = 6); or, 4) low-frequency – sparse (n = 6). Appendix A contains a list of target words, stimuli presented, and their allocated frequency-density category.

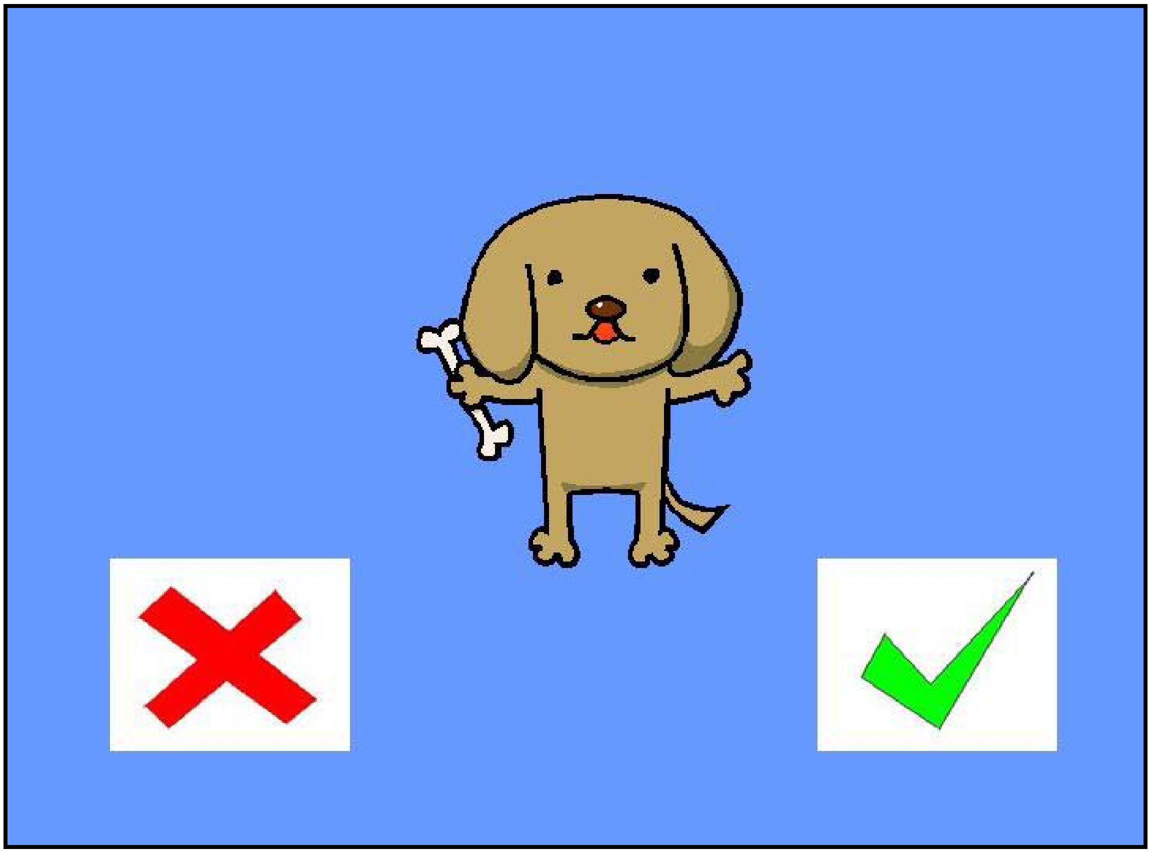

Figure 10. Screenshot of the item "*dog"* presented during the PR judgment task using frequency – density stimuli. The word *dog* was categorized as high-frequency residing in a sparse lexical neighbourhood. Auditory stimuli presented with each slide consisted of either a correct or incorrect pronunciation of the target word.

All stimuli were created by recording a male native New Zealand English speaker using the procedures specified in chapter 2. Mispronounced stimuli were created by altering the vowel sound. For example, the target word *bag* was recorded correctly as /bæg/ and mispronounced as /bɒg/. Ten adult speakers of standard NZ English were then asked to judge the accuracy of task items. This was undertaken to ensure that stimuli were perceived as anticipated (i.e., either correct or incorrect productions of the target words). Several items were discarded after adults could not agree on the correctness of the production.

At the beginning of each assessment session, participants were asked to name the pictures used in the tasks. Phonemic or semantic prompting was provided if a child was unable to name a picture (e.g., a phonemic prime for the word *ship* included "*this is a /ʃ/*"; and, a semantic prime for the word *bag* was "*this is something people carry things in"*). Prompting alternated between phonemic and semantic priming. If children were unable to name the target picture after prompting, the target word was modeled and children asked to imitate the word.

4.2.1.2 Phonological representation task item analysis

Three separate raw scores were calculated for the children's performance on the PR judgment and NW learning tasks presented at each assessment trial during the longitudinal study. Raw scores were then converted to percentage correct scores for analysis. These scores were -

1. Total responses correct;
2. Correct identification of words (PR judgment) and nonwords (NW learning) pronounced accurately according to the standard adult pronunciation. This is described as the A score. As each child's primary caregiver spoke unaccented standard New Zealand English and ten adult speakers of New Zealand English agreed on the accuracy of items, it was assumed that children would also be capable of correctly judging these words.
3. Correct identification of mispronounced words and nonwords (B score).

4.2.1.3 Test item and scoring reliability

Test item reliability was undertaken by performing a classical item analysis of responses for A (correctly pronounced stimuli) and B (incorrectly pronounced stimuli) items for the PR judgment and NW learning tasks presented at each of the 4 assessment trials and for the revised PR judgment tasks. Internal consistency reliability for the PR judgment task B scores at each trial ($a = 0.87$) and the PR judgment task without pictures ($a = 0.80$) yielded coefficient alphas which met the most stringent level of internal consistency (i.e., $a = 0.8$; Nunally, 1978). The PR frequency-density judgment task ($a = 0.66$) and NW learning task B scores ($a = 0.67$) reached an acceptable level of internal consistency. Participants' responses to items on the revised PR judgment task were verified using the same procedures described in chapter 2. The independent examiner's scores were identical to the original scores recorded.

4.3 Results

4.3.1 PR judgment task variants

4.3.1.1 PR judgment task without pictures

Data were first analysed to compare group performance on the PR judgment task without picture stimuli. Separate t-tests were performed to compare the group mean scores. No significant group differences were observed for total items correct (i.e., combined A and B scores) [$t(1,24) = 0.6927$; $p = 0.49$], A [$t(1,24) = 0.3132$; $p = 0.76$] or B [$t(1,24) = 0.6980$; $p = 0.49$] scores. As shown in the comparison of mean group scores provided in Table 6 above and described in chapter 3, significant group differences were observed on the PR judgment task with pictures presented at trial 4. The small effect sizes observed on the PR judgment task without pictures compared to the large effect sizes noted on the task presented with pictures, also suggest the elimination of picture stimuli reduced the effectiveness of the task to determine group differences.

Table 11. *Group performances on PR judgment task with and without picture stimuli*

	SI Group		TS Group			
	M	SD	M	SD	P value	Cohen's *d*
PR judgment without pictures						
- Total	71.56	15.93	76.71	18.83	0.492	0.2952
- A scores	80.56	23.94	83.33	20.20	0.757	0.1250
- B scores	63.25	17.95	70.59	28.56	0.492	0.3077
PR judgment with pictures (trial 4)						
- Total	76.44	13.48	89.41	8.71	<0.01**	1.1428
- A scores	87.04	17.24	94.61	5.85	0.109	0.5880
- B scores	66.67	23.71	84.61	15.14	0.027*	0.9018

Note. SI group = Speech impairment group, TS group = Typical speech development group, Total = combined A and B scores, A scores = correctly judged items that were pronounced accurately, B scores = correctly judged mispronounced items.

** $p < 0.01$, * $p < 0.05$

Data were then analysed to compare within group performances on the PR judgment task with and without pictures. As shown in Table 11, both groups demonstrated superior performance on the task with picture stimuli. Group mean scores for each task were included in separate paired t-tests. No significant differences were observed on performances by the SI group using total [$t(1,8) = 1.5364$; $p = 0.163$], A [$t(1,8) = 0.9375$; $p = 0.38$], and B [$t(1,8) = 0.8835$; $p = 0.40$] scores. Analyses of performances by children in the TS group, however, provided significant differences on the total [$t(1,16) = 3.3643$; $p < 0.01$], A [$t(1,16) = 2.4659$; $p < 0.05$], and B [$t(1,16) = 3.1275$; $p < 0.01$] scores.

4.3.1.2 PR judgment task with frequency – density stimuli

Responses from the PR judgment task using frequency – density stimuli were analysed to investigate the effects of word frequency and neighbourhood density on children's ability to judge the pronunciation accuracy of stimuli. A t-test comparison of the group means on the

PR judgment task using frequency-density stimuli indicated the difference in total scores narrowly failed to reach significance [$t(1,24) = 1.9819$; $p = 0.06$]. A comparison of B scores, however, revealed a significant group difference [$t(1,24) = 2.9516$; $p<0.01$]. A closer inspection of scores based on the different stimuli used on the task indicated a significant group difference on correctly judging low-frequency words from sparse lexical neighbourhoods [$t(1,24) = 2.1696$; $p<0.05$], and all stimuli from sparse lexical neighbourhoods (i.e., both high and low-frequency words) [$t(1,24) = 2.3125$; $p<0.05$]. The differences between group means on high-dense, high-spare, and low-dense stimuli did not reach significance. Table 12 provides a comparison of group mean scores for each type of stimuli.

Table 12. *Group performances on PR judgment task using frequency – density stimuli*

	SI Group		TS Group			
	M	SD	M	SD	P value	Cohen's *d*
Total score	83.11	12.13	91.53	9.26	0.0591	0.7802
A scores	76.54	18.79	80.39	19.46	0.6318	0.2012
B scores	86.81	11.02	95.96	4.91	0.0070	1.0996
High – Dense	84.44	19.44	92.94	12.13	0.1811	0.5246
Low – Dense	85.19	15.47	88.24	18.41	0.6760	0.1793
High – Sparse	86.11	15.87	92.65	12.55	0.2600	0.4571
Low – Sparse	75.93	25.15	92.16	13.33	0.0402*	0.8063
High-Frequency items	85.47	13.57	92.76	8.37	0.1018	0.6466
Low-Frequency items	80.56	15.02	90.20	14.80	0.1290	0.6465
Dense items	84.85	14.37	90.37	12.64	0.3216	0.4079
Spare items	81.75	14.33	92.44	9.27	0.0297*	0.8858

Note. SI group = Speech impairment group; TS group = Typical speech development group; Total = combined A and B scores; A scores = correctly judged items that were pronounced accurately; B scores = correctly judged mispronounced items; High = high-frequency words; Low = low-frequency words; Sparse = words residing in sparse lexical neighbourhoods; Dense = words residing in dense lexical neighbourhoods.

*$p<0.05$

4.3.2 Analyses of A and B scores from the longitudinal study

Item responses from the PR judgment and NW learning tasks presented in the longitudinal study were analysed to determine if group differences existed on the detection of mispronounced stimuli. A two-way repeated measures analysis of variance of B scores from the PR judgment tasks presented at each assessment trial determined a significant group interaction [$F(4,21) = 3.77$, $p<0.05$]. Both time [$F(3,22) = 2.80$, $p = 0.06$] and group by time [$F(3,22) = 0.33$, $p = 0.80$] effects were not significant. Figure 11 illustrates the comparison of mean PR judgment task B scores at each assessment trial. Post hoc testing indicated the group differences at trial 2, 3, and 4 were statistically significant ($p < 0.05$) and the difference at trial 1 narrowly failed to reach significance ($p = 0.08$). A similar pattern was observed for B scores obtained from the NW learning tasks presented in the longitudinal study. Statistically significant group [$F(4,21) = 5.79$, $p<0.01$] and time [$F(3,22) = 3.66$, $p<0.05$] effects were observed. The group by time interaction [$F(3,22) = 0.89$, $p = 0.46$] was not significant. Post hoc testing revealed that group differences were significant ($p<0.05$) at trial 1, 2, and 3. The group difference at trial 4 was close to significance ($p = 0.052$).

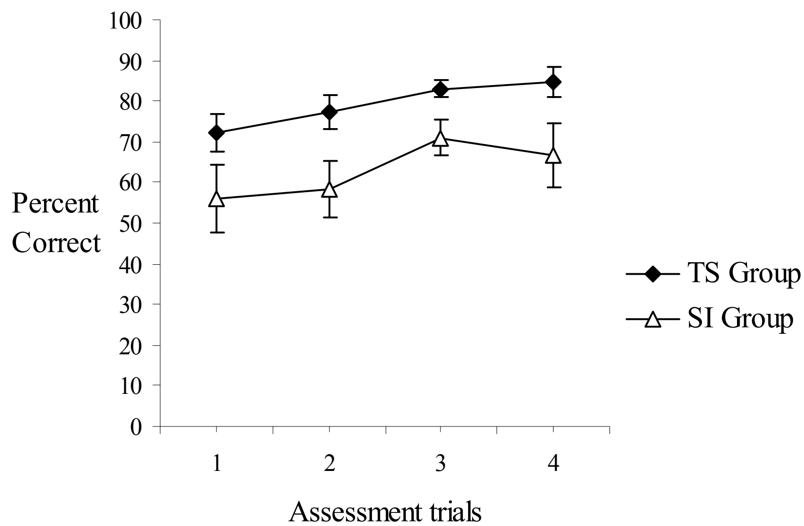

Figure 11. Mean B scores on the PR judgment task at each assessment trial. B scores were obtained by tallying all correctly identified mispronounced items.

Item responses on the PR judgment and NW learning tasks were analysed further to determine if group differences existed in the judgment of correctly pronounced stimuli. A two-way repeated measures analysis of variance was performed using the A scores obtained from the PR judgment tasks presented at each assessment trial. No significant group [$F(4,21) = 1.8680$, $p = 0.15$], time [$F(3,22) = 1.6837$, $p = 0.20$], or group by time

[$F(3,22) = 0.9379$, $p = 0.44$] interaction effects were observed. Figure 12 illustrates the mean A scores recorded on the PR judgment task at each assessment trial. A two-way repeated measures ANOVA was also performed using the A scores from the NW learning task. No significant group [$F(4,21) = 0.7562$, $p = 0.57$] or group by time [$F(3,22) = 0.8150$, $p = 0.50$] interaction was observed. A significant time [$F(3,22) = 11.6694$, $p < 0.001$] effect, however, was observed.

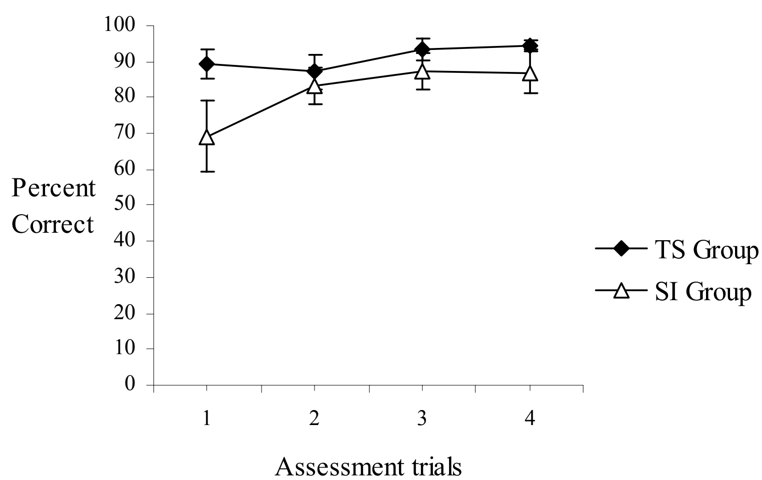

Figure 12. Mean A scores on the PR judgment task at each assessment trial. A scores were obtained by tallying all accurately pronounced items judged correctly.

As a group, children in the SI group demonstrated inferior performance at identifying a range of mispronounced items. To examine the characteristics of specific items that challenged children with speech impairment, separate t-tests were performed on individual mispronounced test items from both the PR judgment and NW learning tasks used across the study. A significance level of $p < 0.10$ was used as the criteria for selecting words and nonwords to ensure a variety of words were selected. A total of 7 real words and 5 nonwords were identified and are shown in Table 13. These stimuli were created by making changes to both stressed and unstressed vowel sounds.

Table 13. *Individual stimuli that contributed to group differences on the phonological representation tasks*

Target Stimuli	Transcription	Description of stimuli alteration
PR judgment task		
- Monster	/mounstə/	lengthen and change stressed vowel
- Caterpillar	/kætaipɪlə/	lengthen and change unstressed vowel
- Ambulance	/æmbjulans/	change unstressed vowel
- Garage	/gærudʒ/	change unstressed vowel
- Dragonfly	/dræginflai/	change unstressed vowel
- Parachute	/pæriʃut/	change unstressed vowel
- Policeman	/pəlusmæn/	change stressed vowel
NW learning task		
- /hekəmaiʃti/	/hekumaiʃti/	change unstressed vowel
- /fɔirælɪb/	/fɔirælab/	change unstressed vowel
- /fleŋgiʃʌm/	/fleŋgʊʃʌm/	change stressed vowel
- /fleŋgiʃʌm/	/fleŋgəʃʌm/	change stressed vowel
- /sprɪmitʃeid/	/sprɪmetʃeid/	change stressed vowel

4.4 Discussion

The investigation reported in this chapter explored the influence of task presentation and stimuli variables on children's performance on the experimental phonological representation tasks presented during the longitudinal study. The first hypothesis examined was that children with speech impairment would perform poorly on the PR judgment task presented without picture stimuli compared to children without speech impairment. The findings did not support this hypothesis, with the group difference failing to reach significance. The PR judgment task without pictures presented at the conclusion of the longitudinal study examined children's use of visual support during a task that required access to underling phonological representations. The elimination of pictures from the task ensured that children accessed phonological representations via the auditory channel only. This was similar to Carroll and Snowling's (2004) mispronunciation detection task presented using live-voice without pictures. In contrast to the current findings, Carroll and Snowling (2004) reported significant group differences between children with and without speech impairment. It was also hypothesised that children in both groups would demonstrate greater difficulty on the PR judgment task without picture stimuli compared to the PR judgment task with pictures. Although the mean performance by both groups was lower on the PR judgment task without pictures, only the decrease observed on the TS group's mean scores reached significance. This finding suggests that the provision of picture support provided some level of phonological priming, similar to that reported during picture naming tasks (Cutting & Ferreira, 1999; Navarrete & Costa, 2005). The results also suggest that children with typical speech development benefit more from this priming than children with speech impairment. This finding is plausible based on the evidence that suggests some children with speech impairment have deficits in their phonological presentations. For these children, the priming effect provided by picture stimuli accompanying auditory stimuli is unlikely to improve their ability to judge the pronunciation of target words.

The second hypothesis tested was that children in the SI group would perform poorly compared to children in the TS group at judging low-frequency words located in sparse lexical neighbourhoods during a PR judgment task. This hypothesis was supported by the data analyses. Significant group differences were observed on children's ability to identify the accuracy of low-frequency items with few lexical neighbours. This result is consistent with Metsala's (1997b) finding that children with reading disabilities have more difficulty than good readers at identifying low-frequency words from sparse lexical neighbourhoods. The small number of low-sparse task items (*n* = 6) in the current study may have contributed to the significance of the findings. The selection of stimuli from Metsala's (1997b) study may also have influenced performances. Theses stimuli were based on adult speakers' judgment of vocabulary usage of older American English speaking children. Further development of stimuli is required to ensure word frequency specifications are consistent with local vocabulary usage and applicable for target age groups. Nevertheless, the significant findings provided support for the further use of PR judgment tasks with different stimuli characteristics.

The third hypothesis examined was that children with speech impairment would demonstrate difficulty detecting mispronounced stimuli on both the PR judgment and NW learning tasks presented during the longitudinal study. It was also hypothesised that no group differences would be observed on the judgment of accurately produced items. A closer inspection and analyses of item responses confirmed these hypotheses with significant group differences observed across the study on mispronounced items from both tasks. No group differences were observed on accurately pronounced items. Compared with children in the TS group, children with speech impairment were more likely to judge a mispronounced word as correct. This finding expands earlier reports of children with speech impairment performing poorly on mispronunciation detection tasks (e.g., Rvachew et al., 2003: Carroll & Snowling, 2004) by specifying that it is mispronounced items that appear to pose difficulty for children with speech impairment.

The fact that children with speech impairment had difficulty judging mispronounced items, yet performed as well as their peers without speech impairment at identifying correctly pronounced words can be explained in terms of Elbro's (1996) distinctness hypothesis. Although these children may have less distinct phonological representations they are able to effectively judge words spoken correctly as words are perceived as close to their underlying phonological representation. These children may not, however, have access to representations that contain enough phonological information to enable them to correctly identify mispronounced words. A further explanation for poor performance of children with speech impairment at detecting mispronounced words is provided by Walley's (1993) segmentation hypothesis. The hypothesis stated that phonological representations become more segmental over time with phoneme-level details appearing for some words before others. Therefore, children with speech impairment may experience difficulties in developing segmental phonological representations for more words than children with typical speech development.

The findings from this study have demonstrated that as a group, children with speech impairment have greater difficulty referencing well-specified phonological representations to determine the accuracy of spoken real and nonwords. There is a need, however, to consider within-group characteristics of children with speech impairment. This information is required to develop knowledge on the relationships between speech, phonological representations, phonological awareness, and early print decoding. For example, consideration of task performances of children with different types of speech impairment such as those described by Dodd, Holm, Crosbie, and McCormack (2005) and Leitão, Hogben, and Fletcher (1997) will help develop our understanding of the links between phonological representations and specific subtypes of speech impairment. These analyses will also help to develop the accuracy of identifying children who may be at most risk of early reading impairment. Chapter 5 contributes to this process by presenting in-depth case studies of four children who exhibited different speech characteristics and performance on experimental tasks during the longitudinal study.

Chapter 5. Case Studies of Four Children with Severe Speech Impairment

5.1 Introduction

The examination of experimental task variables detailed in chapter four indicated that as a group, children with speech impairment performed poorly compared to children with typical speech development on receptive tasks requiring the detection of mispronounced stimuli. Children with speech impairment also performed poorly on tasks examining phoneme-level phonological awareness during the longitudinal study described in chapter 3. These findings provided further support for the relationship between the precision of underlying phonological representations and children's ability to process speech sound information during speech perception and phonological awareness tasks. Although significant group differences were observed on the experimental tasks and phonological awareness measures throughout the longitudinal study, within group variability among children with severe speech impairment was apparent. In addition to those children in the speech impairment (SI) group who performed well below children in the typical speech development (TS) group, several children performed at an equivalent or higher level on non-speech measures. The relationships between speech production skills and performance on phonological representation and phonological awareness measures are examined further in this chapter through the analyses of individual case studies of children with severe speech impairment.

Previous case study reports have highlighted the relationship between speech impairment, phonological processing difficulties, and reading disabilities. Snowling and Hulme (1989) reported a longitudinal study of a child (JM) with dyslexia and speech difficulties. When first assessed at age 8 years 5 months, JM demonstrated above average intelligence (i.e., approximately 1 year above his chronological age), below average reading (i.e., age equivalent of 7 years) and spelling (i.e., age equivalent of 6 years and 7 months) (Snowling & Hulme, 1989). By age 12, JM's reading skills were measured at 2 to 3 years below his chronological age and his spelling ability was equivalent to age 8 years and 11 months. The authors concluded that JM's reading and spelling difficulties were the result of deficits in his knowledge of the relationship between printed letters and corresponding speech sounds (Snowling & Hulme, 1989). This was highlighted by JM's considerable difficulty in reading and spelling nonwords. The poor specification of phonological representations may also have contributed to JM's phonological processing and word recognition difficulties. JM also had a history of speech difficulties and continued to mispronounce a range of words in conversational speech and demonstrated slow articulation of words throughout the four-year study period. He also demonstrated particularly poor performance on multisyllable real and nonword repetition tasks. This case study highlighted the persistent nature of speech impairment and the importance of phonological processing to the development of reading and spelling skills.

Gillon and Dodd (1998) also reported a developmental case study that provided further evidence for the stability of the relationship between phonological awareness deficits and reading disability. An 8-year-old boy (Ben) with dyslexia was studied over a period of 4 years and 4 months. At the first study assessment, Ben's reading was limited to recognition of some single words or equivalent to children 3 years younger (Gillon & Dodd, 1998). He was also unable to spell real or nonwords. In addition to the annual reassessment of reading, spelling, and phonological processing skills, the researchers provided separate phonological awareness and semantic-syntactic intervention programs. The phonological awareness training consisted of 12 hours of one-to-one intervention focused on phoneme-level skills such as segmentation and blending. The phonological awareness training also included instruction on the relationship between speech sounds and printed letters. Although Ben's reading and spelling accuracy developed during the study, notable improvement only occurred during the period of phonological intervention (Gillon & Dodd, 1998). These findings provided evidence for the importance of intervention targeting underlying phonological processing deficits. At age 13, Ben's reading accuracy was approximately 4 years below the level expected for his chronological age, providing further support for the stability of the relationship between phonological processing deficits and reading disability. The researchers also reported that Ben had ongoing difficulty articulating unfamiliar multisyllable words in the absence of any obvious speech development problems. This was interpreted as the child experiencing difficulty creating and accessing new phonological representations (Gillon & Dodd, 1998). Both Ben and JM were selected for their respective case studies based on their reading disability and phonological processing difficulties. Both subjects, however, also demonstrated subtle speech production difficulties, suggesting a shared area of deficit with children who experience speech impairment.

Constable, Stackhouse, and Wells (1997) also reported a case study of a child with severe word finding difficulties influencing his development of speech and literacy skills. The researchers conducted a thorough investigation of the child's auditory discrimination and mispronunciation detection skills together with speech production and naming ability. The child performed poorly on input and output phonological processing measures. This finding indicated that the child's word finding difficulties were likely due to poorly specified underlying phonological representations and poor connections between phonological and semantic representations. The study also provided further evidence for the relationship between speech perception and production difficulties and underlying phonological representations.

The identification of sub-groups of children with speech impairment has important benefits for research and clinical practice. Benefits include helping to identify underlying causes of different types of speech impairment, and development of appropriate intervention techniques (Dodd, 2005). Dodd et al. (2005) proposed four different sub-categories of speech impairment: (a) Articulation disorder; (b) Delayed speech development; (c) Consistent speech disorder; and, (d) Inconsistent speech disorder. Under this classification system, childhood apraxia of speech was specified as a fifth category (Ozanne, 2005). Consideration of these sub-groups and their performance on a range of speech and phonological processing tasks can also be used to infer characteristics of their phonological representations.

Children who demonstrate the consistent use of non-developmental speech errors appear to have difficulty developing and applying knowledge about the phonological rules that determine how speech sounds are combined together in words (Dodd, 2005). In contrast, children demonstrating inconsistent use of non-developmental speech errors are more likely to have deficits at the motor-programming level of speech processing. According to Stackhouse and Wells (1997), the motor-programming level is activated after reference to phonological representations during speech production. Evidence for the different areas of deficit underlying these sub-groups was provided by a comparison of children's preference for nonwords that consisted of phonological *legal* and *illegal* phoneme combinations (Dodd et al., 1989). For example, a legal item was *slerti* and its illegal minimal pair was *zlerti. Zlerti* was considered illegal due to the *zl* phoneme combination not appearing in Australian-English (Dodd et al., 1989). Children identified as consistently using non-developmental speech errors showed no preference for phonologically legal nonwords. In contrast, children with delayed speech development, inconsistent speech errors, and a control group all preferred legal over illegal stimuli. Further support for children with consistent speech impairment experiencing difficulty at the level of phonological representations was reported by Leitão et al. (1997). An examination of phonological awareness skills in children with speech impairment showed that children who consistently used non-developmental speech errors were more likely to have difficulty on phonological awareness tasks such as phoneme segmentation and blending compared to children with delayed speech development or inconsistent speech impairment.

There was, however, some overlap in individual performances on phonological awareness tasks between sub-groups of children (Leitão et al., 1997). This evidence indicates that children with deviant consistent speech impairment are more likely to experience deficits at the level of phonological representations compared to children with delayed speech development or inconsistent speech impairment.

Case studies of four children who participated in the longitudinal study are presented to consider the relationship between the characteristics of speech impairment and performance on the phonological representation, phonological awareness, and early print decoding measures. The four children selected for analysis were Henry, Bryn, John, and Zack. The rationale for the selection for each child and specific hypotheses examined are as follows –

1. Henry's speech was characterised by the inconsistent use of speech sound errors at each assessment trial. Henry also demonstrated the least improvement in his speech production at the final trial. It was hypothesised that he would present with persistent weaknesses on phonological awareness, receptive phonological representation, and early print decoding measures relative to children with typical speech development.
2. Bryn's speech was characterised by numerous speech production errors. In line with Dodd et al. (1989) and Leitão et al.'s (1997) findings, it was hypothesised that he would perform poorly on phonological representation and phonological awareness measures relative to the TS group and the 3 other children from the SI group reported in this chapter (i.e., Henry - inconsistent speech errors; John - speech delay; and, Zack speech delay).
3. Zack's speech was characterised by delayed development. His speech errors were common among younger children experiencing typical speech development. Zack performed well on phonological awareness measures at each assessment trial. It was hypothesised that his performance on receptive phonological representation tasks and early print decoding measures would be similar to children without speech impairment.

4. John also presented with delayed speech development. In contrast to Zack, he performed poorly on phonological awareness tasks at each assessment trial. It was hypothesised that he would also perform poorly on receptive phonological representation and early print decoding tasks compared to children in the TS group and Zack from the SI group.

5.2 Case Study – Henry

5.2.1 Case history

Henry was recruited to the study at age 4 years, 5 months. He had attended preschool for two days a week, and had attended childcare on a part time basis since 15-months-of-age. Henry commenced formal schooling on his 5th birthday, soon after the 2nd study trial. Henry's initial assessment results indicated his speech impairment was severe and characterised by both the inconsistent use of both common and deviant error patterns (see Table 7 and 8 in chapter 3 above). Despite his unintelligible speech, Henry presented as a happy and talkative child at each assessment session. At times, he became excitable and required specific prompting to complete assessment tasks. Henry's mother (Mrs H) reported that he was a sociable boy who was treated well by his peers. Mrs H also reported that Henry lived at home with his father and 2 siblings, an older brother aged 7 years 6 months and a younger sister aged 19 months.

Highlights from Henry's early development included a history of gastroesophageal reflux and middle ear infections. The reflux resolved by approximately 12-months-of-age. At age 17 months he had aeration tubes inserted in both ears. Mrs H reported that he passed all hearing tests administered since insertion of the aeration tubes and no longer experienced middle ear infections. Normal pure tone hearing thresholds and tympanometry were also noted at the first study assessment. Henry's feeding and general motor development histories were reported as typical. Henry's early communication involved the use of gesture and pointing, with his first words appearing around age 2 years. At age 3 years and 8 months, his word productions were characterised by single syllables and isolated vowel sounds. A possible familial tendency for speech problems was raised with a paternal aunty and cousin reported as having a history of speech development problems. Typical speech development was, however, noted for Henry's parents and siblings.

Henry first came to the attention of speech-language therapy services at age 2:8 when he was assessed for poor speech production. At this time he received a brief period of therapy targeting early speech sound production. Henry was reassessed 12 months later at age 3:8. From age 3:8 until trial 4 of the study (i.e., age 5:8), Henry received intervention support from early intervention and school-based speech therapy services. During this time period he received a total of 28 individual intervention sessions (i.e., 21 hours) administered by a speech-language therapist. Intervention was based on the Cycles treatment approach (Hodson and Paden, 1991) and targeted a range of speech errors including final consonant deletion and cluster reduction. He also received preschool and classroom support by a non-professional communication support worker for 1 hour each week. On starting school, Henry participated in a classroom-based phonics training program called *Jolly Phonics* (Jolly Learning, 2005). This program teaches letter knowledge by pairing alphabet letters with letter sounds and manual signs. For example, the letter 'S' is paired with a continuous /s/ sound, and moving one hand using an S-shaped movement to mimic a snake.

At the first assessment trial, Henry performed within the normal range on both receptive vocabulary and receptive language assessments despite an earlier speech-language therapy report noting Henry's receptive language as slightly below an age appropriate level. He provided 49 correct responses (i.e., standard score = 94) on the *PPVT-III* (Dunn & Dunn, 1997) and standard scores ranging from 10 to 12 on the three receptive language subtests of the *CELF-P* (Wiig et al., 1992). Henry also performed within the normal range on an oral-motor screening. Spontaneous language sampling to evaluate his expressive language was not assessed due to the severe unintelligibility of his speech.

5.2.2 Speech

Henry presented with severe speech impairment at each assessment trial. Percent consonants correct scores ranged between 17% and 35% across the study on speech, real and nonword repetition tasks (see Figure 13). Henry's speech production was also highly inconsistent with consistency scores ranging from 64% to 76%. At trial 1, Henry demonstrated a high level of speech sound omissions (i.e., 73% of errors). This included the deletion of almost all final consonant sounds, some medial sounds, and some consonant cluster elements. Non-developmental speech errors used by Henry included inconsistently substituting /v/ for /r/, /f/ for /j/, and /d/ for /f/. The inventory of consonant sounds used by Henry at trial 1 (see Table 14) shows that he used a variety of voiced and unvoiced sounds. Liquid sounds were the only sound class not produced. The glottal fricative /h/ was the only consonant sound produced proximal to the back of the mouth. Henry added several sounds to his inventory during the study. These included /n/ at trial 2 and /j/ at trial 3. Consonant clusters /ps/ and /ts/ were also evident at trial 3.

Table 14. *Henry's consonant inventory at trial 1*

Sound Class	**Consonants produced**
Stops	/p/, /b/ /t/, /d/
Nasals	/m/
Fricatives	/f/, /v/, /s/, /z/, /ʃ/, /h/
Affricates	/tʃ/, /dʒ/
Glides	/w/
Liquids	-

At trial 4, Henry continued to delete a range of sounds including liquids, cluster elements, and fricatives, although omission errors had reduced to 35% of all errors. The percentage of final consonants being deleted also reduced to 17%. All velar sounds continued to be substituted with sounds produced further forward in the mouth. The fricative simplification error pattern was not observed at trial 1, due to the high level of sound omissions. At trial 2, Henry used fricative simplification on 38% of opportunities, this increased to 75% at trial 3, before reducing to 50% at trial 4. Several error patterns displayed a similar increase and then decrease in usage across the study. This was due to the high level of sound omissions exhibited by Henry. His high level of inconsistent speech production may also have contributed to the variation in rate of error pattern use.

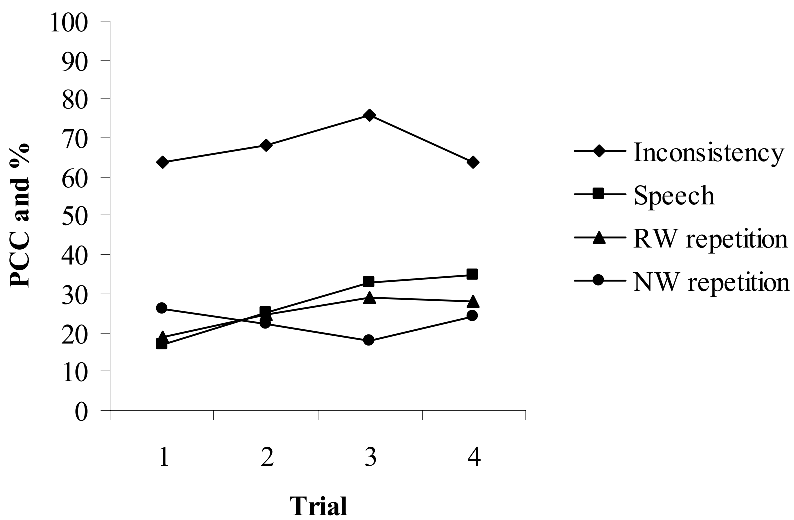

Figure 13. Henry's speech and inconsistency scores at each trial. The inconsistency percentage reported was measured using the inconsistency subtest of the DEAP (Dodd et al., 2000). *Note.* RW repetition = real word repetition, NW repetition = nonword repetition.

5.2.3 Phonological representations

Henry's performances on the PR judgment and NW learning tasks were compared to children in the TS group. As illustrated in Figure 14, he scored significantly below the TS group mean on 6 out of the 8 task presentations. Henry, however, did demonstrate a significant improvement on the NW learning task (i.e., 80% mispronounced items judged correctly) at trial 4. His PR judgment task score at trial 3 was also within -1SD of the TS group mean.

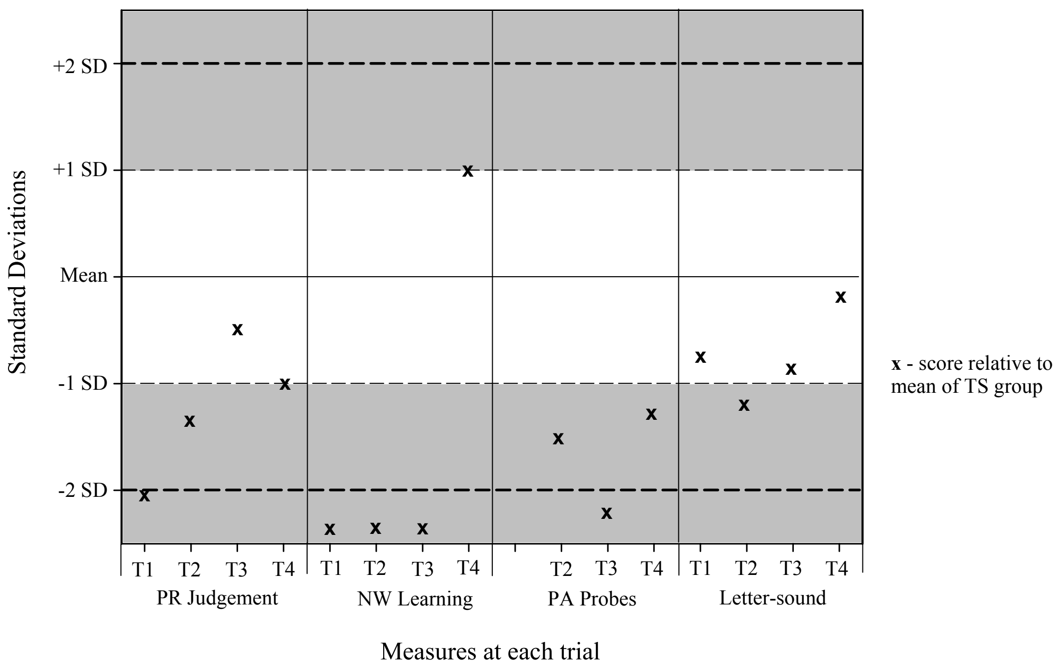

Figure 14. Henry's performance on tasks compared to children with typical speech development. Performance on the PR judgment and NW learning tasks are based on B scores.

5.2.4 Phonological awareness

Henry was unable to provide any correct responses on the PA probe tasks presented at trial 2, and his trial 3 scores were significantly below children with typical speech development. He demonstrated improved performance relative to the control group at trial 4 to a level close to -1SD below the mean. By trial 3, Henry began to demonstrate an ability to identify the first sound in words (i.e., 7 out of 10 correct). He was, however, unable to perform phoneme blending, segmentation or deletion tasks. At the final trial, Henry correctly identified initial (i.e., 10 out of 10) and final (i.e., 9 out of 10) sounds from single syllable words, although he continued to experience difficulty on more advanced phoneme-level manipulation tasks.

5.2.5 Print decoding

Henry correctly read 11 words from the Burt reading test at trial 4. Although his speech impairment influenced his pronunciation of these words, his responses were transcribed and verified as attempts at the correct target words. For example, a correct response was scored for the word *big* which Henry read as /*bɪd*/. Henry's responses on the letter-sound knowledge task also required interpretation has he occasionally provided an incorrect target sound with a correct sign/gesture based on his school-based phonics program. For example, the letter 'k' prompted Henry to raise his hands and click his fingers while saying /t,t,t,t,t/. This was interpreted as the correct gesture (based on the Jolly Phonics program) and the production of /t/ was interpreted as activation of the velar fronting error pattern. Henry was unable to read any complete nonwords or phonemes presented at trial 3. By trial 4, he correctly read 7 initial phonemes.

5.2.6 Summary

Henry's demonstrated inferior performance on all study measures compared to children with typical speech development. He presented with severe speech impairment and made slow progress in speech development despite specific speech-focused intervention. A wide range of developmental and idiosyncratic speech errors were also produced at each assessment trial. Henry also performed particularly poorly on both the PR judgment and nonword learning task at several trials. This indicates the possibility that in addition to speech motor-programming difficulties characteristic of inconsistent speech impairment (Dodd et al., 2005), Henry may also have deficits at a higher level of speech processing involving phonological representations. Although his trial 4 NW learning score was +1SD above the mean of the control group, this may have occurred by chance as it was inconsistent with the pattern of task performance at earlier trials. Results from phonological awareness tasks at trial 4 demonstrated that Henry was beginning to develop awareness of sounds within words, despite his persistent speech difficulties. His ability to read some isolated single words and identify letter-sounds, albeit with the assistance of a phonics-based training program, indicate that his early literacy skills are emerging. The ease with which he will progress to a more phonologically-based word recognition system, however, remains unclear at this point. Henry's persistent and severe speech impairment place him at significant risk of falling further behind his peers in the reading development process (Nathan et al., 2004).

5.3 Case Study – Bryn

5.3.1 Case history

Bryn was aged 4 years and 8 months when referred to the study by his kindergarten teacher. He attended kindergarten from age 3 until commencing school at age 5. Bryn lived at home with his mother, father and 8-year-old sister. Despite his significant speech difficulties, Bryn presented as a cheerful child who was happy to initiate conversation and respond to questions throughout the study. At times during the first two assessment trials, Bryn had difficulty maintaining attention to tasks. This was managed by providing regular play breaks between tasks and shortening the duration of sessions to 30-40 minutes. Bryn's attention skills improved noticeably once he commenced primary school.

Bryn's early development was unremarkable except for his speech production difficulties. One episode of otitis media was noted at around 12-months-of-age. Subsequent hospital-based hearing tests indicated normal middle ear function and hearing ability. The hearing screening conducted at trial 1, confirmed normal sound detection and tympanometry.

Bryn's first words appeared around age 15 months in CV structures. Mrs B reported no concern about Bryn's development of language comprehension skills. Results from the CELF-P and PPVT-III administered at trial 1, confirmed that Bryn's receptive vocabulary and language comprehension skills were within the normal range. Standard scores noted on the receptive language subtests of the CELF-P ranged from 10 for *Basic Concepts*, to 14 for *Sentence Structure*. Bryn also provided 56 correct responses on the PPVT-III which equated to a standard score of 100.

Bryn was first referred to speech and language therapy services at age 2:6. Early speech therapy intervention focused on improving the accuracy of Bryn's speech sound production using a combination of the Cycles and traditional approaches. An early speech therapy report also noted the presentation of oral-motor exercises and auditory discrimination activities. On commencement of school, Bryn received approximately 1 speech therapy session (30-45 minutes) per week for two terms (20 weeks). These sessions were based on the traditional intervention approach and targeted the development of specific speech sounds. He also received classroom support from a teacher aide for two hours each week for 15 weeks. Bryn's speech-language therapist also reported his high level of determination to develop age-appropriate speech.

5.3.2 Speech

Bryn presented with severe speech impairment at trial 1. He produced a PCC score of 29% on the single word elicitation task. Twenty-seven percent of his speech errors involved the deletion of sounds. Bryn's speech was also measured as 40% inconsistent which is considered borderline inconsistent speech (Dodd et al., 2000). An analysis of speech sounds produced at trial 1, revealed that Bryn used a variety of sounds from each sound class, as shown in Table 15. A variety of voiced and voiceless fricatives and affricates were also observed. Bryn also produced several of non-developmental speech errors detailed in Table 6 and 7 above (see chapter 3). These included the predominant use of the affrication error pattern to substitute a wide variety of sounds including /g/ and /k/, and the substitution of /d/ with /tʃ/. The unusual substitution of /t/ with /fw/ was also produced on several occasions. The characteristics of these errors together with the improvement in speech consistency observed at trial 2 and 3 indicated that Bryn's speech impairment could be categorised as *deviant consistent*.

Table 15. *Bryn's consonant inventory at trial 1*

Sound Class	**Consonants produced**
Stops	/p/, /b/ /t/, /k/
Nasals	/m/, /n/, /ŋ/
Fricatives	/f/, /v/, /s/, /z/, /ʃ/, /h/
Affricates	/tʃ/, /dʒ/
Glides	/w/
Liquids	/l/

Throughout the study, Bryn demonstrated steady improvement in his ability to accurately produce speech sounds on single word elicitation and real word repetition tasks (see Figure 15). By trial 4, he produced PCC scores of 83% for single words and 76% for repeated multisyllable words. After showing improvement in his repetition of nonwords at trial 2, Bryn failed to demonstrate further progress between trial 2 and 4. As Bryn's speech inconsistency decreased to 28% and 24% at trial 2 and 3, no further consistency measure was taken at trial 4. At trial 1, Bryn deleted a range of consonant sounds from words, including final consonants, medial liquids, and cluster elements. By trial 4, his omission errors were restricted to the deletion of sounds from consonant clusters. Although Bryn reduced his use of some error patterns (e.g., gliding) across trials, his use of the fricative simplification error (e.g., substituting /θ/ with /f/) pattern increased from 13% to 75%. This increase can be attributed to the elimination of most omission-based errors. This created more opportunities for substitution-based errors to appear. As the fricative simplification error pattern is common in many typically developing children, it is also likely that Bryn received positive reinforcement for its use when attending school. Bryn's use of the affrication error pattern declined across the study. By trial 4, he occasionally produced the affricate /dʒ/ for /d/. In line with the improvements in Bryn's speech sound productions during the study, his speech intelligibility also increased.

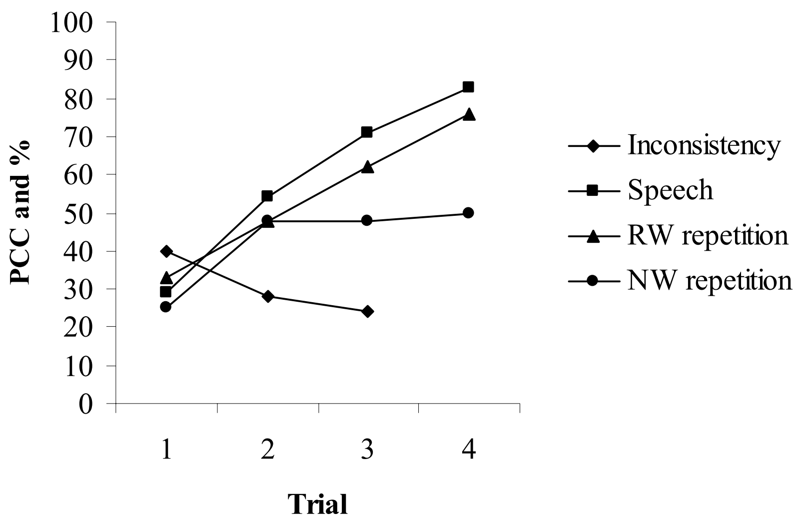

Figure 15. Bryn's speech and inconsistency measures at each trial. The inconsistency percentage reported was measured using the inconsistency subtest of the DEAP (Dodd et al., 2000). *Note:* RW repetition = real word repetition, NW repetition = nonword repetition.

5.3.3 Phonological representations

Bryn's responses on the PR judgment and NW learning tasks varied across the study. As shown in Figure 16, his performance on the PR judgment tasks presented at trial 1 and 2, were significantly below the mean score of the TS group. At each trial, he accurately identified between 90% and 100% of words pronounced correctly, yet demonstrated difficulty judging mispronounced words. He correctly identified 19% of mispronounced words at trial 1, and gradually increased his performance to 76% at trial 4. In contrast, Bryn performed slightly above the average of the control group at detecting mispronounced newly learned nonwords at trial 1 (91%) and 3 (77%). At trial 2, his performance (41%) was below -2 SD from the mean for children with typical speech development.

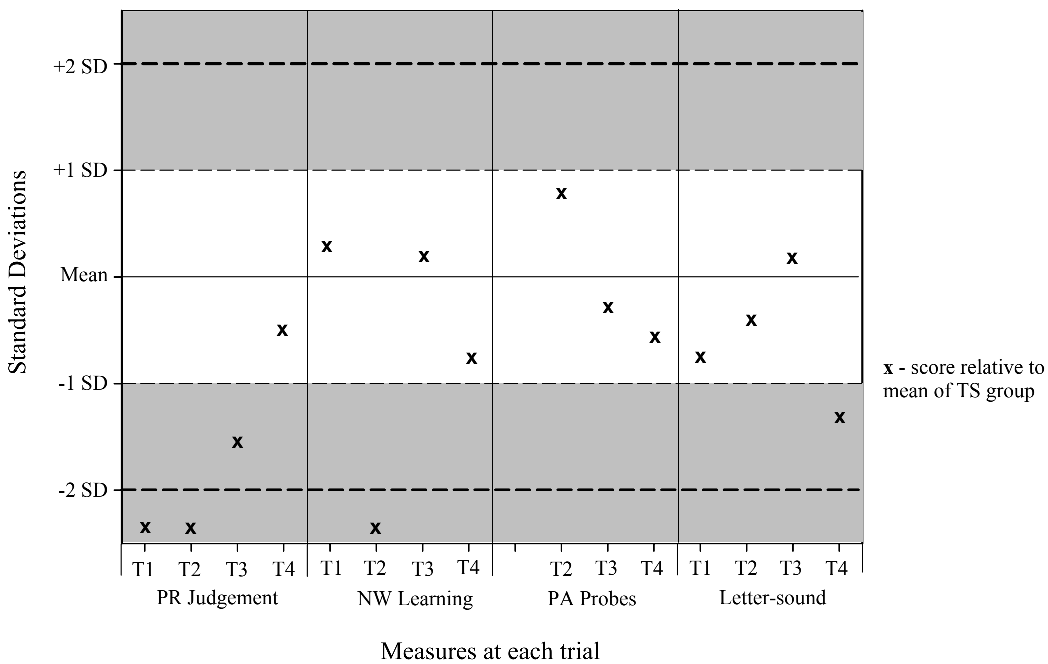

Figure 16. Bryn's performance on tasks compared to children with typical speech development. Performance on the PR judgment and NW learning tasks are based on B scores

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5.3.4 Phonological awareness

Bryn demonstrated phonological awareness skills that were within ±1SD of the mean of the control group across the study, although some variability in his performance was noted. At trial 2, Bryn was able to correctly identify initial and final phonemes from single syllable words, and deleted initial sounds from 4 words to create a new word (e.g., *sat* becomes *at*). When presented with the phoneme deletion task at trial 3, he was unable to provide any correct responses. Similarly, at trial 3 Bryn was able to segment four words correctly, yet at trial 4 he was unable to provide any correct responses on this task. Although he appeared to grasp the concept of segmentation, his responses contained repeated or inserted vowel sounds (e.g., *time* was segmented as /t/, /ʌ/, /ai/, /m/).

5.3.5 Print decoding

Bryn’s ability to identify letter-sounds increased from zero correct at trial 1, to 26 correct at trial 3. At trial 4, his performance dropped slightly to 25 correct. This resulted in a noticeable decrease in his performance relative to the control group (see Figure 16). Double letter combinations such as ‘st’ and ‘qu’ continued to pose difficulty for Bryn at trial 4. Bryn also demonstrated his emerging reading skills by correctly decoding 16 phonemes from nonwords presented at trial 3. Both initial and final phonemes were read correctly, however no complete nonwords were decoded. At trial 4, Bryn read 4 nonwords (i.e., 20 phonemes) and 12 words on the Burt Reading Test.

5.3.6 Summary

At the first study assessment, Bryn presented with deviant consistent speech impairment (Dodd, 2005). He produced a number of uncommon speech error patterns, including the widespread affrication of many consonant sounds. Bryn received speech therapy as a preschooler and for the first 6 months of primary school. Early in the study, Bryn demonstrated a particular difficulty detecting mispronounced multisyllable words compared to the children in the TS group. This result indicated the possibility that some of Bryn’s underlying phonological representations were not well-specified or contained inaccurate information. His performance also supported the notion of children with deviant consistent speech impairment having greater difficulty on tasks requiring consideration of underlying phonological information (Dodd et al., 1989; Leitão et al., 1997). He also provided variable performances on the NW learning task at each assessment trial. Although Bryn’s phonological awareness skills were within ±1SD of the TS group mean, his relative performance decreased during the study. In contrast, his letter-sound knowledge initially increased (trial 1, 2, and 3) and then reached a plateau at trial 4, resulting in a decrease relative to the TS group. Bryn's early nonword reading and word reading performance, however, indicated that he was beginning to grasp the concepts associated with decoding unfamiliar printed words.

5.4 Case Study – Zack

5.4.1 Case history

Zack was the second eldest child recruited to the SI group, joining the study at age 5 years. He had commenced school 3 weeks before the first study assessment. Zack was referred the study by his speech-language therapist. He attended kindergarten for one year before starting school. Both Zack's mother and grandmother reported experiencing childhood stuttering. During the study, Zack presented as a quiet and well-mannered child who was highly attentive to tasks presented.

Zack had a history of middle ear infections that culminated in the insertion of aeration tubes at age 2 years and 8 months. He provided responses within the normal range on both pure tone audiometry and tympanometry testing procedures at the first assessment trial. Zack also demonstrated excellent receptive vocabulary (i.e., PPVT-III standard score = 122) and receptive language (i.e., CELF-P standard scores = 14-15) development. During the six months before, and the 3 months after commencing the study, Zack had received 15 hours of speech-language therapy intervention targeting his speech intelligibility. Intervention utilised both the Cycles (Hodson & Paden, 1991) and traditional approaches to improve his production of fricative and liquid sounds.

5.4.2 Speech

At the first assessment trial, Zack's PCC score of 45% on the single word elicitation measure indicated he had a severe speech impairment. He produced a range of developmental speech errors including, velar fronting, gliding, stopping of fricatives, and cluster reduction.

Accordingly, his speech difficulties were classified as delayed. Although not formally assessed, Zack's speech appeared relatively intelligible compared to other children in the SI group, due to his consistent use of these common error patterns. As shown in Table 16, Zack produced a variety of speech sounds at trial 1, including fricatives and the liquid /l/. No affricates or voiced velar stops were observed.

Table 16. *Zack's consonant inventory at trial 1*

Sound Class	**Consonants produced**
Stops	/p/, /b/ /t/, /d/, /k/
Nasals	/m/, /n/
Fricatives	/f/, /v/, /θ/, /s/, /z/, /h/
Affricates	-
Glides	/w/, /j/
Liquids	/l/

Considerable improvement in the accuracy of Zack's speech sound production was observed between trial 1 (PCC = 45%) to trial 2 (PCC = 77%). This development was also apparent on the real and nonword repetition tasks. As illustrated in Figure 17, Zack's speech sound development tapered between trial 2 and 4. His performance on the nonword repetition task then decreased from trial 3 to trial 4. This is likely to be due to the increase in complexity of task stimuli.

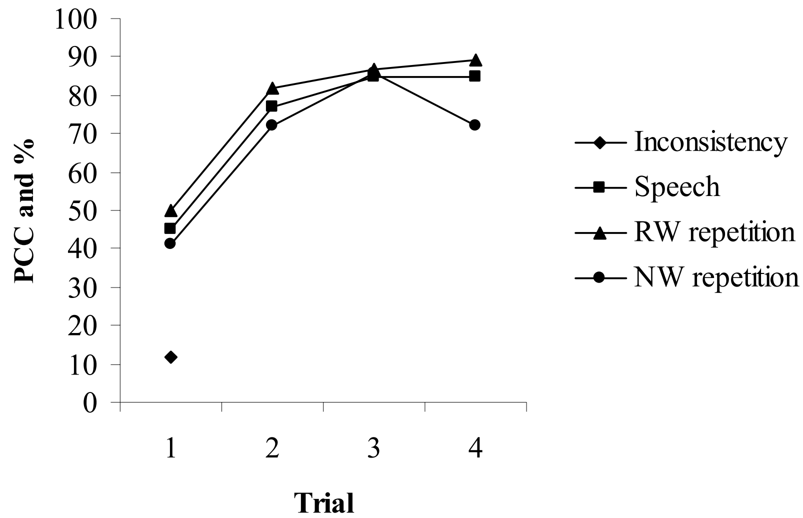

Figure 17. Zack's inconsistency and speech measures at each trial. The inconsistency percentage reported was measured at trial 1 only, using the inconsistency subtest of the DEAP (Dodd et al., 2000). *Note:* RW repetition = real word repetition, NW repetition = nonword repetition.

5.4.3 Phonological representations

Compared with the average scores of children in the TS group, Zack demonstrated variable performance on both the PR judgment and NW learning task during the study. For example, he correctly identified 86% (PR judgment) and 91% (NW learning) of mispronounced items at trial 1. In contrast, he identified 46% (PR judgment) and 40% (NW learning) of mispronounced items at trial 4. Zack also correctly judged an average of 95% of the items pronounced correctly.

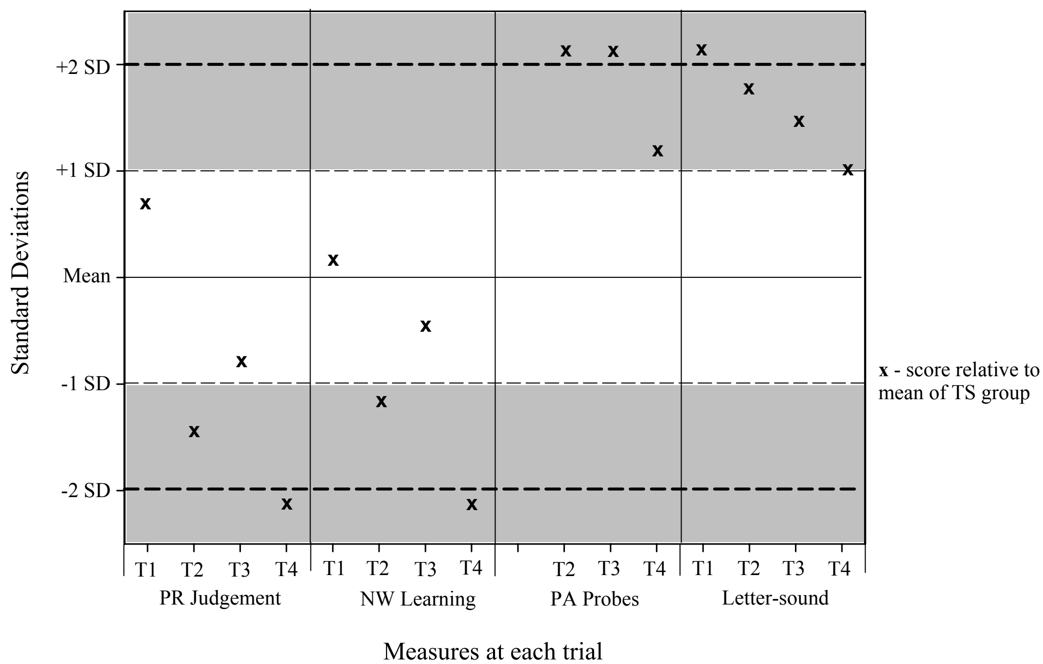

Figure 18. Zack's performance on tasks compared to children with typical speech development. Performance on the PR judgment and NW learning tasks are based on B scores

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5.4.4 Phonological awareness

Zack demonstrated strong awareness of words' phoneme-level detail at each assessment trial. At trial 2, he demonstrated an ability to blend, segment, isolate, and delete phonemes from words. His performances were at ceiling on the phoneme isolation task at each trial and his phoneme deletion scores were 90% and 95% at trial 3 and 4 respectively. The phoneme segmentation subtest was the most challenging for Zack, with approximately 50% of items segmented correctly at each trial. As shown in Figure 18, Zack's performances were well above the average of the TS group at each trial.

5.4.5 Print decoding

Zack's print decoding and word recognition skills became well-established during the study. He was able to identify letter sounds, decode nonwords, and read printed words at each trial. At trial 1, Zack identified 75% of letter sounds correctly, then performed at ceiling at subsequent trials. The increase in the mean score of the TS group at each trial explains the decrease in Zack's performance relative to the TS group illustrated in Figure 18. Zack was able to accurately decode 43% (trial 3) and 60% (trial 4) of nonwords presented. He also correctly read 53 single words on the Burt word reading test at trial 4. This was well above the TS group's mean of 22 words. Zack's superior print decoding skills are likely to have been facilitated by the high volume of joint book reading experiences reported by his mother. These took place several times each day and began soon after Zack's birth.

5.4.6 Summary

Zack was selected for case study analysis due to his delayed speech development and strong phonological awareness skills. Zack demonstrated good progress in his speech sound production between trial 1 and 2. This was also the period during and immediately after he received speech-language therapy services. His post-therapy speech development appeared to reach a plateau, with minimal progress shown at subsequent trials. This pattern of performance is consistent with Gillon & Dodd's (1998) case study report of Ben's improvement in reading and spelling taking place only during periods of intervention.

Several factors may have contributed to the variability in Zack's ability to detect mispronounced stimuli on the experimental phonological representation tasks. He may have experienced subtle hearing difficulties which interfered with his ability to detect the fine-grained changes in the stimuli presented. Zack presented with normal hearing ability at trial 1 and his mother reported no apparent hearing problems each trial, however, no further hearing measures were taken. Zack's history of middle ear infections and simultaneous poor performances on both the PR judgment and NW learning tasks at trial 2 and 4 provided some support for this possibility. Although Zack correctly identified the training items on these tasks he may also have become overly cautious in his judgment of mispronounced items. It is also possible that Zack's underlying phonological representations for the stimuli presented were not well-specified. However, his superior phonological awareness and print decoding skills suggest that he was able to access phoneme-level details of phonological representations. Despite his performance on the phonological representation tasks, Zack appeared to be well on the way to mastering the reading process.

5.5 Case Study – John

5.5.1 Case history

John was first assessed for inclusion in the study at age 4 years and two months. His kindergarten teacher referred him to the study citing his speech as "difficult to understand". John attended preschool for 4 mornings each week from age 4- to 5-years. Two study trials were completed before he started school at age 5. The fourth trial was conducted 7 months after he commenced school. During assessment sessions, John was quiet and reserved, requiring prompting and cueing for general conversation and some task responses. Assessment trial 1 and 2 were each presented over 3 separate sessions due to John's reluctance to respond to several tasks. He also required extra breaks during assessment sessions to help maintain his focus on tasks. Although John's mother was willing to participate in the study, she did not express concern for his speech development, despite demonstrating difficulty understanding his speech.

No birth or early development information was available as John was adopted by Mr and Mrs J at age 9 months. Two to three ear infections were reported as a toddler. Mrs J also recalled that John babbled "some sounds and words" (e.g., /mʌmʌ/) at 9 months, although he was slow to produce additional words. Performance on both the PPVT-III (i.e., standard score = 106) and CELF-P subtests (i.e., standard scores = 9, 10 & 11) indicated John's receptive vocabulary and language skills were age-appropriate. No oral-motor abnormalities were detected at trial 1, and his middle ear function and pure tone detection skills were also noted as within normal limits.

John had no contact with speech-language therapy services prior to joining the study. After the first assessment session, enrolment in a 10-week University-based intervention program was offered to, and accepted by Mrs J. This intervention program took place immediately prior to the 2nd study assessment trial. The intervention involved one individual and one small group-based session each week for 10 weeks. Each session lasted between 35 and 50 minutes. One final year and two 2nd year speech-language therapy students provided intervention during the programme under the supervision of an experienced speech-language therapist. A modified Cycles approach (Hodson & Paden, 1991) was used to target phonemes /k/, /r/ and consonant clusters with initial /s/ sounds (e.g., /st/ and /sm/). Mrs J reported that weekly home practice activities involving speech sound targets were completed. Additional early phonological awareness activities targeting skills such as phoneme identity and phoneme matching were presented during individual and group sessions. Letter-name and letter-sound knowledge skills were also trained during intervention. The 2nd study trial was conducted soon after John completed the intervention programme.

5.5.2 Speech

John’s speech skills increased and then stabilised across the study. As illustrated in Figure 19, his PCC score increased from 52% at trial 1 to 75% at trial 2. The improvement in John’s speech tapered as the study progressed, with a small improvement in PCC scores from trial 2 to 3 (i.e., 75% to 83%), and an even smaller increment between trial 3 and 4 (i.e., 83% to 85%). A similar tapering of performance was observed during the real word repetition task. Greater variability was observed in his nonword repetition skills. A small increase between trial 1 and 2 (i.e., 59% to 61%) was followed by a larger increase at trial 3 (79%). This was followed by a noticeable decrease at trial 4 (52%). John's speech was judged to be consistent at trial 1, with 20% of words produced inconsistently. No further inconsistency measures were taken at subsequent trials.

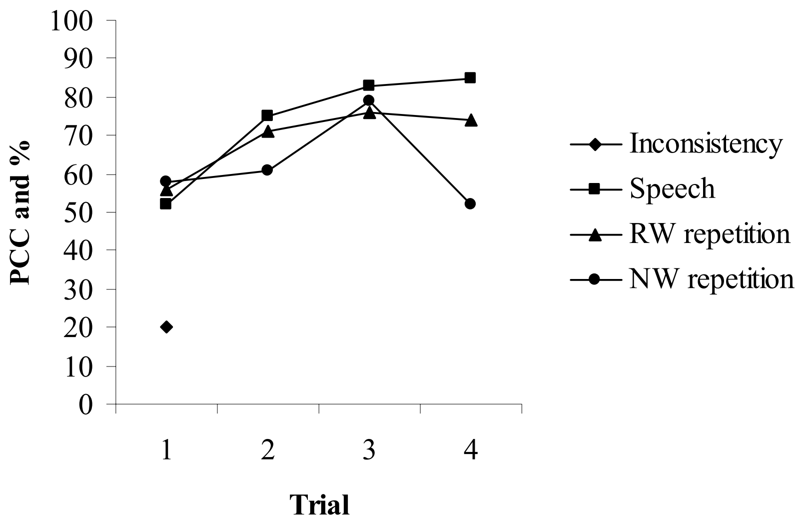

Figure 19. John's inconsistency and speech measures at each trial. The inconsistency measure was taken at trial 1 only.

At the first assessment trial, John's speech sound inventory consisted of sounds from all sound classes. A variety of places of articulation were also represented (see Table 17). The growth in his sound inventory involved the appearance of the fricative /ʃ/ and liquid /l/ at trial 2, followed by the voiced dental fricative /ð/ at trial 4. John also produced a widening array of consonant clusters as the study progressed. At the first trial, John produced a number of speech error patterns including stopping, velar fronting, cluster reduction, and fricative simplification. By trial 4, the only error patterns observed were gliding and fricative simplification. John's use of the fricative simplification error pattern (e.g., substituting /θ/ and /ð/ sounds with /f/) was common to most children in both the SI and TS groups. Several non-developmental error patterns were observed in John's speech at trial 1. For example, in isolated instances, /n/ replaced /ʃ/ and /f/ replaced /s/. As these were the only examples of non-developmental errors observed, John's speech was considered to be delayed as opposed to disordered.

Table 17. *John's consonant inventory at trial 1*

Sound Class	**Consonants produced**
Stops	/p/, /b/ /t/, /d/, /k/, /g/
Nasals	/m/, /n/, /ŋ/
Fricatives	/f/, /v/, /s/, /z/, /h/
Affricates	/tʃ/, /dʒ/
Glides	/w/, /j/
Liquids	/l/

5.5.3 Phonological representations

John consistently demonstrated below average ability at detecting mispronounced real and nonwords compared to children in the TS group. All B scores on the PR judgment task ranged from 52% to 76% correct. As shown on Figure 20, these scores fell in a range of between -0.6SD and -1.5SD from the TS group mean. John's trial 1 performance on the NW learning task (i.e., 45%) was significantly below children with typical speech development. His relative performance on this task, however, increased gradually at each trial with his score of 70% correct at trial 4, being slightly above the average of the TS group.

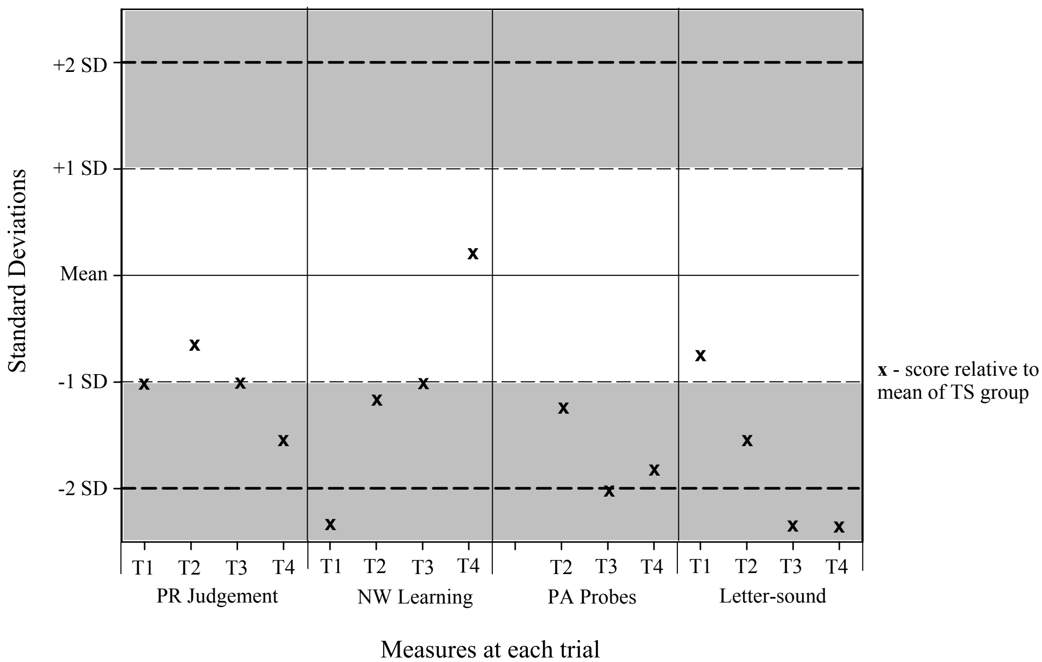

Figure 20. John's performance on tasks compared to children with typical speech development. Performance on the PR judgment and NW learning tasks are based on B scores.

5.5.4 Phonological awareness

John performed poorly on phonological awareness and early reading measures across the study. His only success on phonological awareness tasks was in identifying 100% of initial and 40% of final phonemes of words at trial 4. John was unable to blend, segment, or delete individual phonemes. His level of performance on phonological awareness tasks at trial 3 (i.e., 0%) was significantly below children with typical speech development.

5.5.5 Print decoding

John was unable to read any words presented on the Burt reading test at trial 4, and was unable to read phonemes from the nonwords presented. His performance on the letter-sound task at trial 3 and 4 was also significantly below that of children in the TS group. This was concerning considering John had been at school for 7 months when assessed at trial 4. John's poor letter-sound knowledge and decoding skills indicated that he may experience difficulties developing effective reading and spelling skills.

5.5.6 Summary

John presented with a moderate-severe speech delay at the first assessment trial. He made notable gains in his speech sound production as measured immediately after a period of intervention. His PCC score then appeared to reach a plateau with several developmental speech errors continuing to affect his speech production. The decrease in John's nonword repetition performance between trial 3 and 4 was likely due to the increase in stimuli difficulty. This task appeared to challenge his phonological processing ability and indicated his ongoing phonological processing ability. The possibility of behavioural issues influencing John's performance cannot be discounted as he appeared to lack confidence and became less motivated when presented with more challenging tasks.

Considering John's presentation with delayed speech development, it was expected that he would perform closer to the normal range on non-speech-based assessment tasks (Dodd et al., 1989). However, he performed poorly on measures of phonological representations and phonological awareness. John's inability to read isolated words or manipulate phonemes together with his poor letter-sound knowledge at trial 4, raise questions about his ability to progress in reading development without specific support.

5.6 Discussion

The case studies presented in this chapter described four children who presented with severe speech impairment at the first assessment trial of the longitudinal study. The children were selected due to their diverse speech characteristics and performance on phonological awareness tasks. The first hypothesis examined was that Henry, who presented with inconsistent speech impairment and made the least progress in developing speech sound production skills during the study, would show persistent weakness on all measures compared to children in the TS group. Henry's inferior performances on PR judgment, NW learning, and phonological awareness measures provided support for the hypothesis. His ability to identify letter sounds had undoubtedly been facilitated by the phonics-based training program provided at school, with all verbal responses accompanied by a prescribed physical sign. Although Henry was able to identify several words on the Burt reading test, his inability to read nonwords indicated that he had yet to develop decoding skills. These findings also support the need for well-specified phonological representations to access phoneme-level details during phonological awareness and print decoding tasks (Elbro, 1996; Fowler, 1991; Walley, 1993; Metsala & Walley, 1998).

The second hypothesis stated that Bryn would perform at a level below Henry, John, Zack, and the TS group on the phonological representation and awareness tasks. The hypothesis was based on Bryn's consistent use of deviant error patterns and previous reports of children with consistent deviant speech impairment experiencing greater difficulty than children with other types of speech difficulties, on tasks requiring reflection on phonological information (Dodd et al., 1989; Leitão et al., 1997). Analyses of Bryn's performances provided limited support for this hypothesis. Bryn's ability to detect mispronounced stimuli on the phonological representation tasks was variable in comparison to the TS group with three performances on the NW learning task falling within ±1SD. In contrast, two PR judgment and one NW learning scores were significantly below the TS group mean. His performances were not consistently lower than his peers with speech impairment. For example, Bryn outperformed Henry on phonological awareness and print decoding measures. He also produced several scores higher than John and Zack on the receptive phonological representations measures.

The performance of a child demonstrating delayed speech development and very good phonological awareness skills was analysed to further examine the link between phonological representations, phonological awareness, and print decoding. It was hypothesised that Zack's scores on print decoding and phonological representation measures would be at a similar level to children in the TS group. His superior print decoding skills at each assessment trial supported this hypothesis. Zack's excellent ability to read words, decode nonwords, and identify letter sounds was consistent with his high level of achievement on phonological awareness measures. This finding also highlights the close relationship between phonological awareness and reading acquisition (Adams, 1990; Gillon, 2004). In contrast, his mixed performances on the PR judgment and NW learning tasks did not support the hypothesis. As discussed above, it is possible that his poor performance at trial 2 and 4 on the PR judgment and NW learning tasks was the result of extraneous task presentation and personal variables.

The fourth hypothesis tested was that a child with delayed speech development and poor phonological awareness would demonstrate inferior performance on the phonological representation and print decoding tasks compared to the TS group. Analyses of John's performances supported this hypothesis. His ability to detect mispronounced items on the PR judgment and NW learning task was consistently around -1SD from the mean of the TS group. John's only score to reach the average of the TS group was on the NW learning task at trial 4. This result provides support for the relationship between phonological awareness and the ability to access well-specified phonological representations. The hypothesis also stated that due to John's poor phonological awareness, he would perform at a level below Zack (who demonstrated delayed speech and good phonological awareness) on the phonological representation tasks across the study. Although trial 1 data supported this hypothesis, John then outperformed Zack on 3 out 6 subsequent task presentations. Zack's unexpectedly low performances at trial 2 and 4 undoubtedly contributed to this finding.

The four children examined in this chapter demonstrated unique individual characteristics that can be hidden within group summaries. Each child was unable to perform at the same level as their peers with typical speech development on a number of tasks presented during the study. Variable performances on both receptive-based phonological representation tasks provided mixed support for the use of these tasks to determine information on children's underlying phonological representations. Bryn was the only child examined, to perform consistently at a level close to the mean of the control group on phonological representation tasks. Henry, John, and to a lesser extent, Zack, appeared challenged by both the PR judgment and NW learning tasks requiring judgment of mispronounced items. Henry and John performed poorly on phonological awareness tasks requiring access to phoneme-level information. It should be noted, however, that Bryn and Zack's superior performance on phonological awareness and letter-sound knowledge measures may have been facilitated by speech-language therapy input and greater exposure to formal reading instruction.

These case studies have shown that children, who experience severe speech impairment as preschoolers, are more likely to have difficulty developing phonological awareness and print decoding skills compared to children with typical speech development. For some children, these challenges appear to be linked to the poor specification of segmental phonological representations. The influence of speech production skills on the development of phonological representations is examined further in the following chapter by considering a child who is unable to communicate effectively using speech.

Chapter 6. A Case Study of a Child with Complex Communication Needs

6.1 Introduction

A majority of children with complex communication needs (CCN) fail to develop effective reading and spelling skills (Dahlgren-Sandberg & Hjelmquist, 1996a, 1996b; Foley & Pollastek, 1999; Vandervelden & Siegel, 1999). These children often experience significant physical and/ or intellectual disabilities and as a consequence, struggle to develop the use of speech to communicate (Jones et al., 1996). In addition to neurophysiologic and cognitive factors, additional environmental factors also contribute to poor literacy outcomes for these children. Environmental factors include less and poor quality exposure to literacy learning opportunities (Koppenhaver & Yoder, 1993) and parents, teachers, and people with CCN themselves holding low expectations for literacy outcomes (Light & McNaughton, 1993). Phonological awareness deficits may also preclude the development of effective literacy skills for children with CCN (Clendon, Gillon, & Yoder, 2005). Reading and spelling abilities are essential for these children to maximise the generative capabilities of modern high-tech AAC systems to facilitate full participation in family and community life. There is a need to determine if the phonological awareness and reading deficits experienced by children with CCN are due to deficits in phonological representations.

The importance of articulatory feedback to the development of phonological representations was highlighted by Vihman's (1982) relexification route of phonological development. Therefore the lack of tactile and acoustic articulatory feedback available to children with CCN, may contribute to the development of weak or poor quality phonological representations. In turn, poorly specified phonological representations are unlikely to support the development of phonological awareness (Fowler, 1991; Elbro, 1996). The relationship between phonological representations and phonological awareness development in a child with CCN is examined in this chapter through the presentation of receptive measures during a longitudinal study.

Recent research has investigated children's ability to cognitively represent phonological information, and to demonstrate phonological awareness in the absence of effective articulation skills. Dahlgren-Sandberg and Hjelmquist (1996a) compared the development of phonological awareness skills in children with CCN and children with typical development. The two groups were matched on age (range = 4:8 to 7:3) and cognitive skills (IQ range = 69.8 to 135.7). Children were presented with 4 tasks to measure their phonological awareness abilities. A phoneme blending task required children to select the correct picture of a word based on the presentation of the word's segmented phonemes. A rhyme judgment task required children to select pairs of pictures based on rhyming words, from an array of 10 pictures. The phoneme identity task involved an examiner presenting isolated consonant and vowel phonemes, located in initial, medial, or final position of target words. Participants then pointed to the picture representing the word containing the target phoneme. The fourth task investigated children's ability to detect word length. This involved the presentation of four pictures together with the spoken name of each picture. A correct response required the selection of the picture representing the word with the most phonemes. As a group, children without speech impairment demonstrated stronger performance than the experimental group on the phoneme blending and word length tasks. However, these differences did not reach statistical significance. Participants' letter name, spelling, and reading skills were also examined. Children in the control group were significantly better at reading and spelling than children with CCN (Dahlgren-Sandberg & Hjelmquist, 1996a). Considering the close links between phonological awareness and early literacy development, this finding was unexpected. It was concluded that the inferior reading and spelling performance by children with CCN was partly due to a difficulty in accessing and manipulating stimuli at a phoneme-level. Foley and Pollastek (1999) added that although the children with CCN may have developed some basic level of phonological awareness, their inferior reading skills did not provide the necessary circular support to further enhance awareness of, or access to phoneme-level information.

In a follow-up study of the children in Dahlgren-Sandberg and Hjelmquist's (1996a) study, Dahlgren-Sandberg (2001) added phoneme deletion and segmentation tasks to the original measures used. The only significant group difference was observed on the earlier measure of word length identification. Vandervelden and Siegel (1999) criticised aspects of Dahlgren-Sandberg and Hjelmquist's (1996a) methodology, arguing that the priming effect created by naming pictures for participants immediately before task presentation may have positively influenced performance of children with CCN.

Vandervelden and Siegel (1999) investigated the phonological awareness and literacy skills in two groups of children and adolescents with CCN and two reading-age matched control groups. Children with CCN were allocated to either an AAC user group, or a group that relied on speech to communicate. The children who did not use AAC were noted as presenting with a range of speech intelligibility ratings (i.e., 5% to 80%) based on a standardised intelligibility assessment. Participants were also presented with a range of phoneme and rime-level awareness tasks. For example, a phoneme identity task required children to recognise if a phoneme was present in a spoken word. Further complexity was added to this task by requiring children to identify if a target phoneme was the first or last sound. Significant group differences were observed on rhyme and phoneme awareness tasks between both groups of children with CCN and the control groups (Vandervelden & Siegel, 1999). Despite being well matched on reading ability, children with CCN also performed poorly on phonological recoding measures using a range of nonword stimuli. For example, a nonword reading task required children to select one of two printed nonwords (e.g., *sed* and *ked*) that sounded like a real word (i.e., *sed*). Comparison between children with CCN found that children using AAC had more difficulty judging rhyming words than children who had limited speech skills. The results confirmed the notion that children with CCN have greater difficulty creating and accessing phonological representations, particularly at sub-lexical levels.

Smith (2001) provided a comprehensive interpretation of the greater propensity of adults with CCN to incorrectly judge nonwords as real words compared to children with typical speech development. Although both groups were matched on reading ability, speaking children were less likely to judge nonwords as real words. Smith (2001) suggested that different developmental experiences with spoken language may have influenced performance on this task. Children with typically developing speech are regularly provided feedback on which to base repair and refinement of their production of spoken words. In comparison, children and adults with CCN are likely to have received minimal direct feedback on any incorrect perception of words or attempts at speech production. These experiential differences may result in poorly or even incorrectly specified phonological representations on which to compare incoming stimuli (Smith, 2001). Therefore on hearing a nonword, adults with CCN may base lexical decisions on inferior phonological representations enabling nonwords to be judged as real words. For example, when presented with the nonword /trin/, a person with CCN may match this with a poorly specified phonological representation for the word *train*.

The following case study investigated the relationship between phonological representations, phonological awareness, and print decoding skills in a child with CCN. The receptive phonological representation tasks described in chapters two and three, together with receptive phonological awareness and early print decoding measures were presented to a child (pseudonym Emma) with severely limited speech production. Her performance was compared to children with typically developing speech skills and similar language and cognitive abilities. The specific hypothesis examined was that Emma would demonstrate inferior levels of performance on receptive phonological representation, phonological awareness, and print decoding measures compared to younger children with typically developing speech skills.

Emma was referred to the study by her parents after study information was distributed to her school.

6.2 Case history

Emma presented with a diagnosis of spastic hemiplegia with a suspected element of ataxia. She was a full-term baby who experienced significant complications during birth. Emma attended all assessment sessions with her care provider (pseudonym Jackie), who was a trainee speech-language therapist. Jackie reported working with Emma for the past 7 years, and identified Emma's wide range of motor and communication development difficulties. Emma's disability was not formally diagnosed until age 4. Emma was ambulatory, although her gait was slow and unsteady. Her significant motor difficulties also resulted in regular drooling and severe speech impairment. Jackie also highlighted Emma's limited social opportunities due to her communication and physical impairments.

Although Emma attempted to use a range of spoken words to communicate, her speech was characterised by severe dysarthria and was highly unintelligible. Jackie reported that Emma experienced regular communication breakdowns with familiar communication partners, and was unable to use speech to communicate with strangers. Jackie reported a perception that Emma was capable of more complex expressive language than she produced. Observation of Emma's expressive language revealed the attempted use of some single words and short phrases, although the words produced were mostly unintelligible. Emma supplemented her speech attempts with a range of communication methods. These included informal gestures such as pointing, head nodding, and facial expression. During the study she also demonstrated an ability to articulate isolated phonemes.

Emma had a history of alternative and augmentative communication (AAC) system use. Her early AAC systems included a variety of communication books and an early Voice Output Communication Aid (VOCA) with a fixed display containing 9 message options. Between trial 1 and 2 of the study, Emma received a *Chat-PC*, a dynamic display voice output

AAC device. The dynamic display and touch screen provide a number of input options including, an alphabetic-input mode with word prediction technology. Although not formally tested, Emma demonstrated an ability to input 1-2 initial alphabet letters and then select some predicted words. Jackie reported Emma's preference for speech attempts and gesture over using the Chat-PC. Speech therapy intervention had been focussing on Emma's use of the Chat-PC for approximately 12 months prior to trial 3. Emma also had access to touch-screen computer technology at home and school. This was used to access a variety of educational and entertainment software.

Emma's formal education began at age 5, at a Conductive Education unit based at a mainstream school. She attended this unit until age 13, sharing time between the mainstream school environment and the specialised unit. Conductive Education provides holistic educational support for children with significant physical disabilities. Originally developed in Hungary by Professor András Petõ, the primary aims of the approach include the development of an active lifestyle, an ability to think, communicate, and interact (Focus2000, 2006). Throughout her educational career, Emma received speech-language therapy intervention approximately twice each week during school terms. This intervention focused on a number of goals including speech sound production, developing pre-reading skills such as letter-sound knowledge, and AAC system use. AAC-based intervention included the operation of the Chat-PC, building vocabulary knowledge and developing Emma's ability to interact with a range of people using the device. She also received full-time teacher aide support when in the mainstream class environment. The main role of her teacher aide was to adapt classroom curricula activities to an appropriate level for Emma's learning needs and abilities.

6.3 Method

At the first assessment session Emma was aged 11 years and 9 months. Her hearing ability was examined using pure tone testing and tympanometry. Emma provided responses within normal limits on these measures. No history of middle ear disease or hearing impairment was reported.

6.3.1. Assessment tasks

Emma participated in three assessment trials. Each trial involved 2 to 3 assessment sessions. Trials were separated by 7 months (trial 1 and trial 2) and 9 months (trial 2 and trial 3). Baseline assessment measures taken at trial 1 included –

1. Receptive vocabulary (PPVT-III; Dunn & Dunn, 1997);
2. Receptive language (CELF-P; Wiig et al., 1992);
3. Non-verbal intelligence (Test of Nonverbal Intelligence-3; TONI-3) (Brown, Sherbenou, & Johnsen, 1997);
4. Burt word reading test (Gilmore et al., 1981);
5. PIPA (Dodd et al., 2000);
6. Receptive phonological representations tasks (PR judgment, NW learning and Receptive Gating).

The Burt word reading test together with the PR judgment and NW learning tasks were presented again at trial 2 and 3. Emma's subsequent phonological awareness development was examined by administering the PIPA at trial 2 and an adapted version of the PA probes at trial 3. An adapted nonword reading task was also presented at trial 3.

Emma's severe dysarthria precluded the use of any speech-based assessment tasks. At the initial assessment session, Emma demonstrated reliable and accurate pointing. Therefore, no adaptations were needed for presentation of the receptive judgment tasks. The Burt word reading and nonword reading assessments were converted to enable Emma to provide meaningful responses. These tasks adaptations are described below.

6.3.1.1 Phonological awareness probes

The presentation of three of the four phonological awareness probes subtests were adapted to eliminate the need for Emma to provide spoken responses. The phoneme isolation task was administered without adjustment. The phoneme blending and phoneme deletion subtests were converted to multiple choice tasks, based on presentation of auditory stimuli. For example, the following instructions were used during the phoneme blending task – *I am going to say some words in a secret code, spreading the sounds out until they come out one at a time. Then I am going to say some words and I want you say yes when I say the secret code word and say no if I say a different word.* Similarly, the phoneme deletion task was presented with the following training instructions – *I am going to say a word…learn. If I take away the first sound /l/ from 'learn', it makes a new word 'earn'. I want you to think about what new word I make when I take away the first sound of a word. Then I will say some words. You say yes when I say the new word. If I say the wrong word, you say no.* These instructions were presented slowly during several training items together with feedback to support Emma's understanding of the task. Test items were introduced after she had provided two consecutive spontaneous correct responses on training items. Several item response options required repetition for Emma to provide a response. Selections were noted as correct if Emma attempted *yes* or nodded immediately after presentation of the target item.

6.3.1.2 Burt word reading

Words from the Burt word reading test were presented via a Microsoft® PowerPoint® slideshow. Each word was presented on the notebook computer along with two distracter words. Figure 21 contains an example slide for the target word *went*. Target word position on screen varied between slides. Distracter items were developed by changing 1-2 phonemes or letter combinations to create real and nonwords. Several distracter items were phonologically correct with incorrect spelling (e.g., *beeleaf* and *belief*). A full list of target and distracter items is contained in Appendix F.

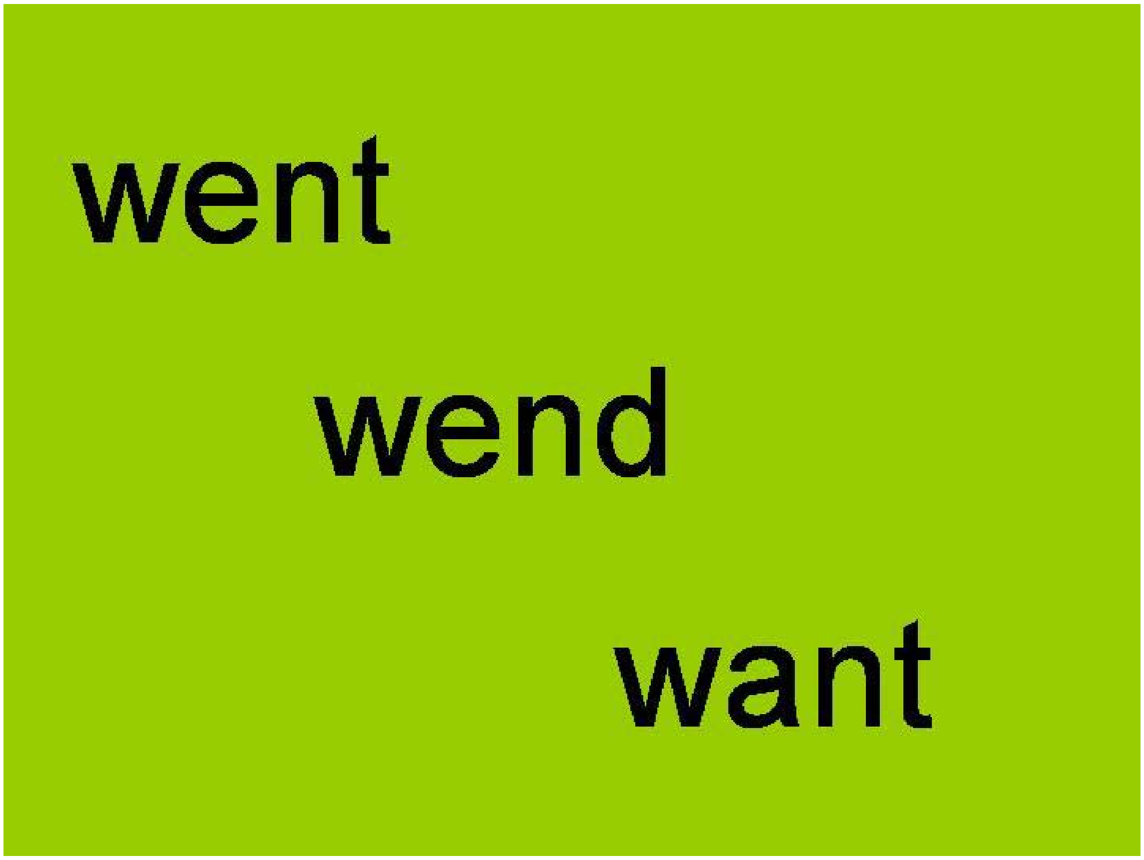

Figure 21. Screenshot of target word "went" on the receptive word recognition task. This task was adapted from the Burt word reading test (Gilmore et al., 1981).

Prior to presentation of this task, Emma was instructed to point to the word on the screen that matched the word read out to her. She was also asked to provide *don't know* or a head-shake as a response if the target word was unfamiliar. During the presentation of the task she appeared to reliably point to target words.

6.3.1.3 Nonword reading task

The nonword reading tasks was also adapted to enable Emma to complete the task without the need to articulate responses. Similar to the Burt word reading task described above, the nonword reading tasks was presented using a PowerPoint® slideshow. Each target nonword was presented with 2 distracter items that varied by 1 phoneme. Creation of distracter items required 1 or 2 changes to letter combinations in the printed nonword. Task instructions included asking Emma to point to the best target for the nonwords spoken by the examiner. She was also asked to respond *don't know* if she did not know the answer. Task slides were similar to Figure 21 shown above for the adapted Burt word reading test. Each slide contained the target nonword (e.g., *mov* /mɒv/) and two distracter items (e.g., mouv, moov). Appendix G contains a full list of distracter items for each target nonword.

6.3.1.4 The Preschool and Primary Inventory of Phonological Awareness

All subtests of the PIPA were presented to Emma. She was able to complete the syllable segmentation, rhyme awareness, and alliteration awareness subtests without added support. The phoneme isolation subtest requires children to articulate the first sound in single words (e.g., shoe = /ʃ/). Emma was able to articulate most sounds in isolation. Several sounds were misarticulated (e.g., /tʃ/ was produced closer to /ʃ/). Two experienced speech-language therapists verified interpretation of Emma's articulated responses on both the phoneme isolation and letter-sound subtests. Emma was not able to articulate all phonemes for any words during the phoneme segmentation subtest. She was, however, credited with a correct response if she selected the appropriate number of counters to represent phonemes. It is acknowledged that is allowance violated the test presentation protocol and is likely to have resulted in an over estimation of Emma's ability on this subtest.

6.4 Results

6.4.1 Receptive vocabulary

Emma correctly identified 86 items (i.e., standard score = 66) from Form A of the PPVT-III at trial 1. This performance was approximately -2.5SD below the mean for children of the same chronological age, as specified in the test manual. Her scores equated to age equivalent performance for children aged approximately 5 years, based on age equivalent scores provided in the test manual.

6.4.2 Receptive language

Based on Emma's level of performance on the PPVT-III, the receptive language subtests of the CELF-P were selected to measure her receptive language development. The use of the CELF-P also enabled a comparison of her performance on this measure with results from other children in the study. The three subtests were presented at trial 1 in accordance with the test administration protocol specified in the test manual. Emma provided 16 correct responses on the linguistics concepts subtest. The items she provided incorrect responses for were based on the concepts of *either, or, before,* and *after.* Basic concept subtest words that Emma had difficulty with were *bottom* and *different*. Emma performed well on the sentence structure subtest, providing one incorrect response on the selection of the correct picture to match the phrase *the boy is crying because his plane is broken*. Emma's performances on these tasks indicated that her understanding of language concepts and structure was at approximately the same level as 5-year-old children with typical language development.

6.4.3 Nonverbal intelligence

The TONI-3 was presented to Emma at trial 1. Her performance of 8 items correct indicated that her nonverbal intelligence approximated to an age equivalent of 6 years and 6 months.

6.4.4 PR judgment task

The PR judgment task was presented at each assessment trial. As shown in Figure 22, Emma correctly identified all items spoken correctly at each trial. Her ability to identify mispronounced words was less accurate with scores ranging from 35% at trial 3 to 60% at trial 2. A comparison of Emma's B scores with the mean of the children in the TS group (see chapter 2 and 3 above) is provided in Figure 24. Her performances were between -1SD and -2SD from the mean of the TS group.

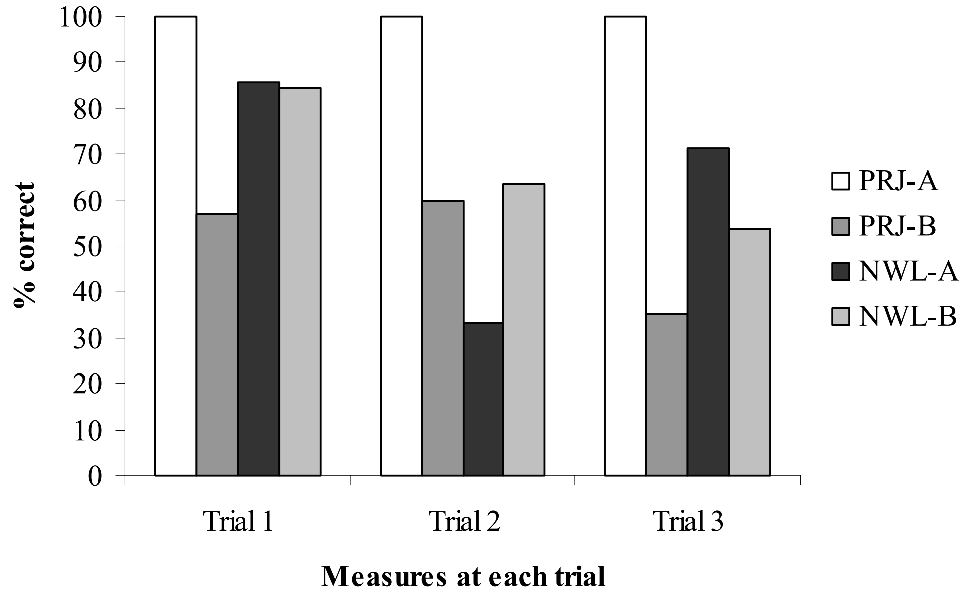

Figure 22. Emma's performance on PR judgment and NW learning tasks at each trial. PRJ = PR judgment task; NWL = NW learning; A = Correctly pronounced items; B = Mispronounced items.

6.4.5 NW learning

Emma had difficulty correctly identifying both mispronounced and correctly pronounced items on the NW learning task. Her best performance was at trial 1 when she identified both types of stimuli with 85% to 86% accuracy. In contrast, at trial 2 she scored 33% for correctly pronounced nonwords and 64% of mispronounced nonwords. As illustrated in Figure 23, Emma's B scores were within -1SD of the mean of the TS group at trial 1 and 2. At trial 3, her performance was -1.6SD below the mean.

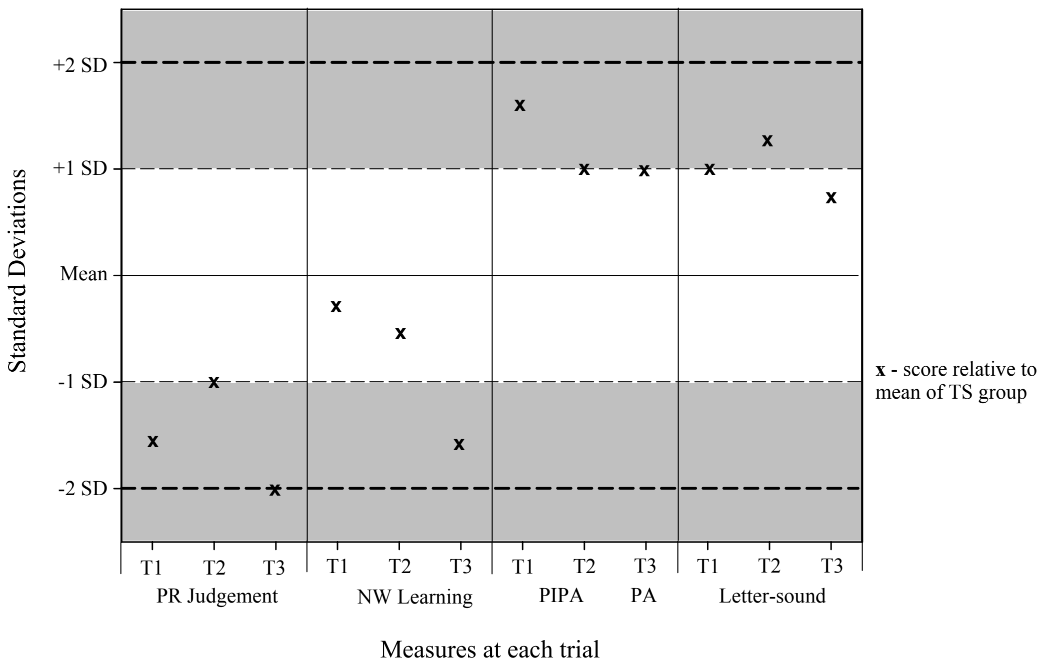

Figure 23. Emma’s task performances compared to the mean of the TS group. PR judgment and NW learning B scores (correct identification of mispronounced items) are reported. Combined PIPA and PA probe scores are reported.

6.4.6 Phonological awareness

All subtests of the PIPA were administered at trial 1 and 2. At trial 1, Emma’s overall performance was +1.6 SD above the mean of children with typical speech development (see Figure 23). Her scores on the syllable segmentation and alliteration awareness subtests both decreased between trials. She performed at ceiling on the phoneme identity subtest at both trials. The increase from 2 to 7 items correct on the rhyme awareness subtest provided the most notable increase between trials.

The adapted PA probe assessments were presented at trial 3 only. On the phoneme identity measure, Emma correctly identified 10 out of 10 initial and final phonemes. She had difficulty on both the phoneme blending and phoneme segmentation task, scoring 1 correct response from 10 items presented on each task. Emma was able to correctly identify 4 out of 20 new words created by deleting the first or last sound from a word. Her performance on these tasks at trial 3 was +1 SD above the mean of children with typical speech development. This observation was made without considering the influence of the task adaptations.

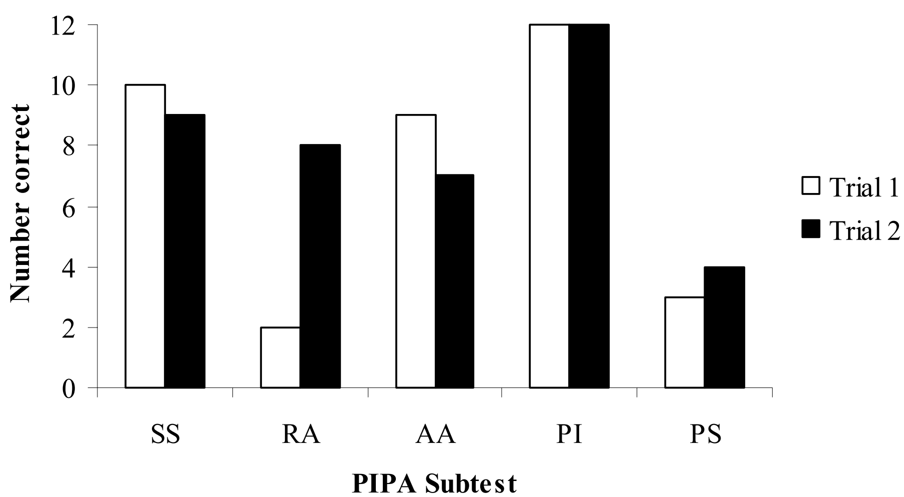

Figure 24. Emma's PIPA subtest performance at trial 1 and 2. Raw scores are reported.

6.4.7 Letter-sound knowledge

In comparison to younger children with typically developing speech, Emma demonstrated above-average letter-sound knowledge across the study. Her performance increased from 11 sounds correct at trial 1 to 26 sounds correct at trial 3. The individual letters and letter combinations that Emma was unable to identify corresponding sounds for at trial 3 were *i, u, e,* and *qu.*

6.4.8 Print decoding

At the first assessment trial, Emma identified the written form of 28 single spoken words during presentation of the adapted Burt word reading test. This increased to 30 (trial 2) and 35 (trial 3). Emma's trial 3 score was slightly below the mean of children with typical speech development measured at trial 4. As noted in the test scoring manual, her performances equated to reading age ranges from 6:06 to 7:0 (trial 1) to 7:01 to 7:07 (trial 3).

During presentation of both the Burt word reading and nonword reading assessments, Emma was able to indicate that she did not know the target word or that her response was a guess. Based on this observation, and the relative consistency of the Burt scores at each trial, the results appeared to be a fair reflection of Emma's abilities. Emma appeared to have difficulty with the nonword reading task, taking considerable time to respond to items. Although she correctly identified 5 out of the 30 items presented, she acknowledged her responses were random responses.

6.5 Discussion

This case study reported the performance of Emma, a child with CCN, on phonological representation, phonological awareness, and print decoding measures at 3 assessment trials over a 16-month period. Although Emma attempted to use speech to communicate, it was highly unintelligible to unfamiliar people. Her performance on receptive language and nonverbal intelligence measures indicated that her abilities were equivalent to children with typical development aged around 5- to 6-years or approximately 6 to 7 years below her chronological age. This gap between chronological age and performance on conventional language and cognitive measures is consistent with previous reports of children and adults with CCN (Dahlgren-Sandberg & Hjelmquist, 1996b; Foley & Pollastek, 1999).

The hypothesis examined was that Emma would demonstrate inferior performance on measures of phonological representation, phonological awareness, and print decoding compared to children in the TS group from the longitudinal study described in chapter 2 and 3 above. The results provided support for and against the hypothesis. Emma demonstrated relatively poor performance on the receptive phonological representation tasks, yet comparatively strong phonological awareness and print decoding skills. Emma had particular difficulty detecting mispronounced multisyllable words on the receptive PR judgment task. At each of the 3 assessment trials, she performed at ceiling for correctly pronounced items. In contrast, she correctly judged less than half of the mispronounced items at trial 3. This is consistent with the findings reported by Smith (2001) who reported adults with CCN making significantly more false positive errors on a lexical decision task using auditory stimuli compared to children with typical speech development. Although Emma's ability to identify correctly pronounced words indicated the possibility that she had access to correctly specified phonological representations, her difficulty in identifying mispronounced items indicates that for some words, her phonological representations maybe more holistic and without access to segmental components. For example, her representation of the word *caterpillar* may allow her to judge the stimuli /kætəpɪlə/ as correct. When presented with the stimuli /kætaipɪlə/, however, she was unable to identify or sufficiently analyse the second vowel sound to determine it was inappropriate.

The NW learning tasks presented at trial 2 and 3 were difficult for Emma. Although her performance at trial 1 was successful, with over 80% accuracy at identifying both correct and mispronounced versions of the nonwords presented, trial 2 and 3 results were either below or slightly above chance levels for both correct and mispronounced items. This indicates that the alterations made to increase the NW learning task difficulty at trial 2 and 3 may have resulted in the task becoming too difficult for Emma. Nevertheless, her performance at correctly identifying mispronounced items at trial 2 (64%) was within -1SD of the mean score of children with typical speech development. Her performance at trial 3 (54%) moved further from the mean of the TS group (-1.6 SD). This may be indicative of children with typical speech development becoming comparatively more effective at using the reduced auditory exposures to the stimuli to develop phonological representations on which to base judgment decisions.

Analysis of phonological awareness assessment results indicated that Emma's early phonological awareness skills were developing above the level of children with typical speech development. However, several task requirements and personal factors require consideration when interpreting results. Emma’s best result was on the initial phoneme identity task on which she scored 100% for both presentations. The small decrease in performance on both the syllable segmentation and alliteration awareness tasks between trial 1 and 2 indicated that these skills were not yet consolidated. The increase in rhyme awareness may have reflected development of this level of phonological awareness. Although a small increase in her phoneme segmentation score was observed, this may be due to the task adaptations of crediting presentation of the correct number of counters, as opposed to articulated speech sounds.

The adapted probe assessments presented at trial 3 further highlighted Emma’s strengths and weaknesses in phonological awareness. She displayed an excellent ability in isolating first and last sounds in words. Her performance on the phoneme deletion task demonstrated her emerging ability to hold a word in memory while deleting the initial phoneme to create a new word. Her difficulty with blending and segmenting phonemes indicates that she experiences difficulty identifying and manipulating phonemes that occur after the initial phoneme. These performances must be considered in the context of task adaptations. Apart from the phoneme identity task, the PA probe items did not require spontaneous response generation, with multiple choice selections provided. Chance performances, therefore, were a possible confounding factor. Additionally, an increased memory component was created by presenting the response choices using live speech without supporting visual stimuli. Conversely, it is possible that the reliance on auditory perception and short-term memory storage may have resulted in an underestimation of Emma’s skills in this area.

Emma’s performances on the letter-sound knowledge task and Burt word reading test were above the average of younger children with typical speech development. These results are likely to be a reflection of her age and considerably greater experience in educational settings, one-on-one intervention sessions, and exposure to literacy learning contexts. Her performance on the Burt indicates that her visual word recognition ability is at least equal to her receptive language and cognitive development. Again, task adaptations may have resulted in an overestimation of Emma's word recognition ability. Interpretation of her nonword reading task performance was difficult due to Emma indicating that her correct responses ($n = 5$) were based on random responses.

In summary, Emma demonstrated above-average early phonological awareness and word recognition ability compared to younger children with typical development. Her performances on the receptive phonological representation tasks, however, were consistently below that of younger children. What is not known regarding Emma's future reading skills is how effectively she will learn to use a phonological decoding strategy for unfamiliar words. Previous research indicates that children with her level of communication difficulties are challenged by more advanced reading activities. These difficulties may well be a direct result of poor quality phonological representations and difficulty accessing these representations. The fact that Emma's word recognition skills were at a level commensurate with her language and cognitive abilities provides some evidence that she may continue to develop skills along a relatively normal trajectory. However, when considering her phonological awareness skills it must be remembered that the tasks were adapted for Emma. Further development of the adapted tasks, and presentation to larger numbers of children with and without CCN, is required to ensure they are reliable and valid. Further consideration of the phonological representation tasks presented in this study and performances on these tasks by Emma and children in both study groups are considered in further detail in the following general discussion.

Chapter 7. Discussion

7.1 Introduction

This thesis reports a research project that investigated the relationship between phonological representations, phonological awareness, and early print decoding ability in young children with speech impairment. Extensive research has highlighted the robust relationship between phonological awareness and reading (see Adams, 1990; Gillon, 2004). As a group, children with speech impairment demonstrate poor phonological awareness development, and are at risk of persistent reading difficulties (Carroll & Snowling, 2004; Larivee & Catts, 1999; Nathan et al., 2004). Several researchers have proposed that phonological awareness development is dependent on changes in the structure and level of detail available in underlying phonological representations (Elbro, 1996; Fowler, 1991; Walley, 1993). The purpose of the current study was to investigate if differences existed between children with and without speech impairment in the storage of phonological representations in long-term memory. Group and individual differences in speech, phonological awareness, and early print decoding skills were also examined.

This research project had a number of aims. The first aim was to develop receptive assessment tasks that enabled examination of children's underlying phonological representations. The second aim was to use these experimental tasks to identify group differences in phonological representations of children with moderate to severe speech impairment and children with typical speech development. Children's performance on the phonological representation tasks was measured over an 18-month period to determine if changes took place as children's speech production improved, and as children were exposed to formal reading instruction. Of particular interest was whether children's early ability to decode print was related to their performance on the phonological representation tasks. Performances on the phonological representation tasks were compared with results from measures of phonological awareness and speech development to determine the relationship these skills share with phonological representations. The final aim of the study was to explore the relationships between the development of phonological awareness, print decoding, and phonological representations in a child with cerebral palsy who had limited articulation ability.

To address these research aims, three receptive assessment tasks were created to examine children's phonological representations. Development of these tasks overcame the inherent difficulties associated with analysing severely impaired speech output to determine information on phonological representations. A group of nine children with moderate to severe speech impairment, and a group of 17 children without speech impairment, participated in a longitudinal study over an 18-month-period beginning when children were aged 4- to 5-years. The two groups were matched on age, receptive vocabulary, and receptive language ability at the first assessment trial. In addition to the phonological representation tasks, measures of phoneme-level phonological awareness, letter-sound knowledge, and nonword and real word reading tasks were also presented to gauge children's development of these skills. The study used single word elicitation, and real and nonword repetition tasks to track the development of speech skills. Performances on these tasks were used to investigate the relationship between speech production and underlying phonological representations. The experimental tasks were also presented to a child with cerebral palsy and complex communication needs (CCN) to examine the influence that an absence of effective articulation skills has on the development of phonological representations. Adaptations were made to the phonological awareness and print decoding measures for presentation to this child.

7.2. Evidence to Support Hypotheses

7.2.1 Initial presentation of phonological representation tasks

The first hypothesis specified that group differences would be observed between children with and without speech impairment, on three novel assessment tasks designed to examine phonological representations. The hypothesis was confirmed with the identification of significant group differences on the PR judgment and NW learning tasks at trial 1. Children with speech impairment demonstrated significantly poorer performance on both tasks, compared to children with typical speech development. No group differences, however, were observed on the receptive gating paradigm task presented at trial 1. The use of this task was discontinued for subsequent assessment trials. The large effect sizes ($d > 0.5$) identified between group performances on the PR judgment and NW learning tasks, suggested that these tasks were appropriate to measure group differences in children's phonological representations. The poor performance of children with speech impairment on these two tasks was consistent with research that has identified this population experience difficulty judging the accuracy of spoken words.(Carroll & Snowling, 2004; Rvachew et al., 2003).

Previous studies have identified that children with speech impairment have difficulty on judgment tasks using mispronounced items created by substituting consonant segments (Carroll & Snowling, 2004; Rvachew et al., 2003). The current study investigated whether similar difficulties are observed when mispronounced items are created by manipulating vowel sounds. The significant group differences observed between the children with and without speech impairment suggest that children with speech impairment experience deficits in the storage of vowel sounds within their phonological representations, compared to children with typical speech development. The findings from the current study also suggest that some children with speech impairment may have similar phonological representation deficits to those reported for children at risk of and with reading disability (Elbro et al., 1998; Thyer & Dodd, 2005).

Children with typical speech development and children with speech impairment appeared to benefit from the provision of picture support during presentation of the PR judgment task. Children's performance on an adapted PR judgment task, that included the presentation of auditory stimuli without accompanying picture support, was compared to performance on a task using the same auditory stimuli with picture stimuli. It was hypothesized that the performance of both groups would decrease without the support of picture stimuli. Although both groups demonstrated reduced performance, the level of decrease shown by children with typical speech development was significantly greater than children with speech impairment. This finding suggests that, to some degree, both groups of children relied on the picture presented during the task, to access their underlying phonological representation of the target word. Based on the assumption that some children with speech impairment have deficits in their underlying phonological representations, however, the priming influence of picture support may be redundant. The results were consistent with Rvachew et al.'s (2003) finding of group differences at judging the correctness of four single-syllable words with accompanying picture support. In contrast, the findings were not consistent with those of Carroll and Snowling (2004) who reported group differences on a mispronunciation detection task without the use of picture support.

7.2.2 Persistent phonological and print decoding deficits

The second hypothesis examined whether children with speech impairment would demonstrate reduced performance, compared to children with typical speech development, on measures of phonological representations and phonological awareness at each assessment trial over an 18-month period, and on the early reading measures taken after school entry. This hypothesis was confirmed by the significant group differences observed on the PR judgment and NW learning tasks across the study. Children with speech impairment also demonstrated inferior phoneme-level awareness at each assessment trial. Although no significant group differences were observed on early print decoding tasks, qualitative differences were observed between children's ability to decode printed nonwords. After approximately 1 year of formal education, more children with speech impairment were unable to decode any printed letters within nonwords.

Despite the significant group differences observed on the PR judgment task, children with and without speech impairment demonstrated increased performance on the PR judgment task at each assessment trial. This finding provided some evidence for children developing access to more segmental components of their underlying phonological representations as they mature (Fowler, 1991; Walley, 1993). In contrast, the decrease in group performance on the NW learning task between trial 1 and 3, is likely to have resulted from the increase in task difficulty. Different stimuli were used for each version of the task to ensure children were not familiar with the stimuli. The consistently poor performance by children with speech impairment suggests that, as a group, they may experience greater difficulty processing and storing phonological information about words despite improving speech production skills.

An examination of variables influencing performance on the PR judgment and NW learning tasks was undertaken to strengthen the assumption that children's performance on these tasks provided information relating to underlying phonological representations. Post hoc analyses of item responses from the PR judgment and NW learning tasks presented at each assessment trial, demonstrated that children with speech impairment had particular difficulty detecting mispronounced stimuli compared to children with typical speech development. There were no significant group differences, however, on the judgment of correctly pronounced items. These group differences support the argument that some children may have phonological representations that enable the recognition of correctly pronounced words, yet their representations are not well-specified at the phoneme-level, making the detection of mispronounced items difficult.

The group differences observed across the study on the NW learning task, suggest that as a group, children with speech impairment have greater difficulty integrating phonological information into some form of mental representation. These children may also experience short term phonological memory deficits similar to those reported for children with typical speech development who perform poorly on nonword repetition tasks (Gathercole, 1995b; Gathercole, Hitch, Service, & Martin, 1997). These deficits are likely to restrict a child's ability to create accurate phonological representations (Adams & Gathercole, 2000). The rationale for the development of the nonword learning task was to challenge children's ability to rapidly develop new phonological representations for unfamiliar words (nonwords). Immediately after the presentation of the training items, children were asked to judge the accuracy of spoken examples of the target nonwords. Although this task was challenging for both groups, children with speech impairment were significantly poorer at judging mispronounced stimuli at assessment trial 1, 2 and 4.

The demands of the NW learning task require consideration before interpreting the group differences on this task. As presented, the task was not necessarily a true reflection of how children learn new words or develop phonological representations. Children were provided multiple exposures to stimuli within a relatively short timeframe with the expectation they would be capable of creating a phonological representation based on these exposures. Learning words in real life occurs more gradually, through multiple exposures to words in a variety of contextual situations. Therefore, as Gathercole (1995a) suggests for nonword repetition tasks, it is possible the NW learning task is more of an examination of children's short term phonological memory. The findings are, however, consistent with research that has reported children with specific language impairment experiencing difficulty learning new words (Oetting, Rice, & Swank, 1995; Rice, Oetting, Marquis, & Bode, 1994).

The influence of the lexical neighbourhood density and frequency of stimuli use on accessing phonological representations were also explored using an adapted PR judgment task. The stimuli used on this task were developed by Metsala (1997b) to investigate the frequency-density effect on children's ability to retrieve words from memory. The finding that children with speech impairment were more likely to have difficulty judging mispronounced low-frequency words from sparse lexical neighbourhoods provides contrastive evidence for the frequency – density effect on the retrieval of lexical items (Luce, Pisoni, & Goldinger, 1990). The frequency – density hypothesis states that the frequency with which words are used, combined with the number of phonetically similar words stored in long term memory, influences children's ability to recognise these words. Accordingly, high frequency words from spare lexical neighbourhoods should be easier to retrieve from the lexical store, compared to words with many phonetically similar words, or words that are accessed infrequently. Children with reading disability have been shown to experience difficulty retrieving infrequently used single-syllable words residing in sparse lexical neighbourhoods (Metsala, 1997b). The findings reported in this thesis suggest that some children with speech impairment experience a similar difficulty. These children had greater difficulty detecting mispronounced words from sparse lexical neighbourhoods, suggesting that their phonological representations for these words were not accurate. Although the results reported here were based on a small number of stimuli, they provide further evidence to enhance the Neighbourhood Activation Model of spoken word recognition (Luce & Pisoni, 1998). The findings are further reinforced by children's performance on the PR judgment task presented during the longitudinal study. The multisyllable words used in this task were relatively low-frequency words with few lexical neighbours. This finding also provides a link to Metsala's (1999) report that stimuli characteristics such as the age at which words are acquired, and lexical neighbourhood density influence children's performance on phonological awareness tasks.

It was also hypothesised that children with speech impairment would demonstrate reduced performance on measures of phonological awareness at each assessment trial and on the early print decoding measures at the final two trials compared to children with typical speech development. The significant group differences observed on the phoneme-level phonological awareness tasks during the longitudinal study supported this hypothesis. This finding adds to previous reports of children with speech impairment experiencing difficulty accessing sub-syllable components of words (Bird et al., 1995; Carroll & Snowling, 2004; Rvachew et al., 2003; Larivee & Catts, 1999). The non-significant group differences observed on the combined PIPA subtest scores at trial 1 and 2 warranted the introduction of measures that demonstrated an increased sensitivity to differences in phonological awareness. The phonological awareness probes (Stahl & Murray, 1994) presented during the study, provided an appropriate test of children's ability to access and manipulate phonemes. This was evidenced by the significant group differences observed on 3 out of the 4 subtests across the study. Children with speech impairment had more difficulty than children in the control group on the phoneme identity, segmentation, and blending tasks. No group difference was observed on the phoneme deletion task. This was likely due to the superior performance of two children with speech impairment on this task. Consistent with Gillon (2005), these findings suggest that children with speech impairment are able to develop rime- and syllable-level awareness, however, appear to struggle in their ability to access phoneme-level segments.

The letter-sound knowledge task was the only measure of print decoding presented during the study that provided significant group differences. A similar weakness in letter-name identification has also been reported for children with speech impairment (Webster, Plante, & Couvillion, 1997). Conversely, Rvachew et al. (2003) reported no difference between children aged 4 years 6 months with and without speech impairment, on letter-name and a measure of early literacy knowledge. These inconsistent results on letter knowledge tasks for children with speech impairment may result from methodological differences between tasks. For example, Dodd and Carr (2004) demonstrated that young children find recalling sounds of letters more challenging than selecting letters based on names and sounds. Differences in children's speech production ability may also influence findings. The finding that children with speech impairment have poor letter-sound knowledge and phonological awareness compared to children with typical speech development provides support for a bidirectional relationship between phonological awareness and letter knowledge prior to children commencing school (Burgess & Lonigan, 1998).

Despite group differences in letter knowledge and phonological awareness, no significant group differences were observed on either the nonword or real word reading tasks at trial 3 and 4. This result can be explained by the strong performance of two children with speech impairment, who performed well above the mean of children without speech impairment on the real and nonword reading tasks. Qualitative group differences, however, were apparent. When children were aged 5- to 6-years, a greater proportion (i.e., 44% vs. 5%) of children with speech impairment were unable to read any complete nonwords or letters within nonwords. The New Zealand year 1 classroom curriculum is predominantly whole-language-based with some grapho-phoneme-based instructional components (Ministry of Education, 1994). Despite exposure to an average of 12 months of this type of literacy curriculum, and a range of speech therapy interventions to enhance speech intelligibility, around half of the children with speech impairment continued to have difficulties on phonological awareness and print decoding tasks. These inferior phoneme-level awareness skills, together with the reduced performance on the phonological representation and print decoding tasks, are supportive of a link between the ability to access well-specified phonological representations and early reading development (Elbro et al., 1998).

7.2.3 Development of speech production

It was expected that children with speech impairment would demonstrate improvement in their speech production skills at each trial, yet significant differences between groups would remain at the final trial when children were aged 6 years. The data supported this hypothesis. The speech accuracy of children with speech impairment improved at each trial as demonstrated by: (a) steady increases in PCC scores on the single word elicitation and real word repetition measures; and, (b) the reduction in specific speech error patterns evident for individual children. Nevertheless, as a group, children with speech impairment performed below children with typical speech development across the study, with significant group differences in PCC scores remaining at the final assessment trial. This finding is consistent with studies demonstrating the persistent nature of preschool speech impairment (Nathan et al., 2004; Hesketh, 2004; Shriberg, Gruber et al., 1994). These results, however, contrast with Gillon's (2005) findings that 3- to 4-year-old children with moderate to severe speech impairment had normalised speech production by age 6. This finding highlighted the influence of the types and intensity of intervention on speech outcomes. Children in Gillon's (2005) study received an average of 19 hours intervention between the ages of 3 and 5, targeting speech intelligibility, phonological awareness, and letter knowledge. In comparison, children in the current study received an average of 13 hours intervention between ages 4 and 6. This intervention focussed mostly on improving speech intelligibility. Additionally, the differing types of intervention were not detailed in a previous longitudinal study reporting speech sound normalisation by around 8-years-of-age (Shriberg, Gruber et al., 1994). These contrasting findings highlight the need for careful monitoring for the effect of intervention on long-term speech outcomes.

7.2.4 Positive relationships between phonological measures and print decoding

The third hypothesis examined was that children's performance on the phonological representation tasks would positively correlate with their performance on phonological awareness and print decoding measures. The results supported this hypothesis with a number of moderate correlations (i.e., *r* = approximately 0.5) between measures of phonological awareness and phonological representations. Evidence for these relationships was stronger between performance on the PR judgment and NW learning tasks at trial 1 and 2, and the phoneme-level awareness probes presented at trial 3 and 4, suggesting the development of more distinct underlying phonological representations in preschool is related to phonological awareness ability post school entry. There is a need, however, to present these tasks to a larger cohort of children to increase the statistical power in investigating the predictive ability of phonological representation task performance for subsequent phonological awareness and reading outcomes.

A similar pattern of decreasing correlation coefficients was evident between performance on phonological representation tasks and print decoding skills. Larger coefficients were identified between performance on the phonological representation measures at trial 1 and 2 when children were aged 4- to 5-years, and decoding measures at trial 3 and 4 when children were aged 5- to 6-years, compared to the concurrent correlations between the two variables. The notable exception was the significant relationship between the letter-sound knowledge performance at trial 4 and scores on the PR judgment task at trial 3. The increased difficulty of the NW learning tasks, together with the corresponding decrease in both group's average performance, is also likely to have contributed to the observed pattern of correlations between variables at later assessment trials. Similarly, ceiling effects on the PR judgment task and floor effects on the early decoding tasks may also have influenced these correlations. This pattern can also be explained by a reduction in the influence of phonological representations on print decoding outcomes as children are exposed to reading instruction. This explanation is consistent with the decreasing influence of phonological awareness skills on reading outcomes, as children are exposed to literacy instruction (Hogan et al., 2005). Nevertheless, the moderate correlations observed, together with the group differences on the phonological representation and phonological awareness tasks provide further support for children with speech impairment experiencing phonological representation deficits that, in turn, affect their ability to analyse words at the phoneme-level.

It was also hypothesised that performance on the phonological representation tasks would correlate with speech production skills early in the study. This hypothesis was confirmed with significant correlations observed between speech performance and scores on the PR judgment and NW learning tasks at trial 1 and 2. This finding is consistent with the central role of phonological representations in providing a cognitive basis for the production of speech (Locke, 1983; Stackhouse & Wells, 1997). Therefore, children with imprecise or poorly specified phonological representations are likely to demonstrate at some degree of speech difficulty. Evidence for this is provided by reports of children with phonological awareness and/ or reading disability and suspected phonological representation deficits, demonstrating subtle speech errors, particularly when producing multisyllable words and nonwords (Elbro et al., 1998; Gillon & Dodd, 1998; Snowling & Hulme, 1989; Swan & Goswami, 1997). The second component of this hypothesis was that correlations between speech production and performance on the phonological representation tasks would decrease as the study progressed. This hypothesis was based on the assumption that some children would demonstrate resolving speech difficulties, yet fail to develop well-specified phonological representations to enhance performance on the experimental tasks. This hypothesis was supported with lower coefficients recorded between performance on the phonological representation tasks and speech skills at trial 3 and 4, compared with the significant correlations between these measures at trial 1 and 2. Many of the trial 3 and 4 correlations, however, continued to be in the moderate range.

7.2.5 Case studies of children with speech impairment

The within-group variability observed in the performance of children in the speech impairment group, on a range of measures across the study, prompted an in-depth examination of four children with speech impairment. One child with speech impairment met Dodd's (2005) criteria for a classification of inconsistent speech impairment with the other 8 children in this group predominantly demonstrating either consistent deviant speech impairment ($n = 4$) or delayed speech development ($n = 4$). The four children selected for analyses presented with a variety of speech error characteristics. These children's performance on phonological representation, phonological awareness and print decoding measures was individually compared with the mean performance of the children with typical speech development. It was hypothesised that Henry (inconsistent and severe speech impairment), James (delayed speech), and Bryn (consistent deviant errors with improved speech performance) would perform consistently below the mean of the control group on all measures. Zack was expected to perform at least as well as children in the control group on phonological representation measures, consistent with his superior performance on phonological awareness and print decoding measures at each assessment trial.

Each child performed significantly below the control group on both the PR judgment and NW learning task on at least two trials. These children also provided at least one performance on each task, equal to or above the control group mean. This finding is compatible with Bird and Bishop's (1992) report of several children with speech impairment group performing at or above the level of typically developing children on one-off phoneme discrimination measures. As Walley (1993) suggested, the segmentation process affecting phonological representations is likely to occur for some words before others. The change in stimuli used on the PR judgment task, therefore, is likely to have contributed to the variability in performances, with children judging some words more easily than others. Additionally, considering the response criteria of pointing to either a tick or cross, for both the PR judgment and NW learning tasks, the possible influence of random responses cannot be discounted.

The examination of the case studies provided mixed support for Dodd et al.'s (1989) and Dodd's (2005) sub-typing of speech impairments. In line with performance of children with consistent deviant speech, it was expected that Bryn would experience difficulty on phonological representation and phonological awareness tasks. His poor performance on the PR judgment task at trial 1 and 2, supported Dodd et al.'s (1989) argument that children with consistent deviant speech impairment experience deficits at the cognitive-linguistic level of speech processing (i.e., the level where phonological representations are located). Conversely, Bryn's average performance on phonological awareness measures at trial 2, 3, and 4 did not support the cognitive-linguistic deficit hypothesis for consistently deviant speech impairment. According to Dodd (2005), children with delayed speech development are not at risk of phonological awareness deficits. Consideration of the performance of two children demonstrating delayed speech development, however, provided contrasting evidence for this hypothesis. James performed poorly on phonological awareness and print decoding tasks, whereas, Zack demonstrated consistently superior phonological awareness and print decoding skills. The analyses of these children's performances indicated variability in the relationships between speech skills and performance on the phonological representation and phonological awareness measures. The heterogeneity among children in the speech impairment group in the current study highlighted the importance of considering individual skills when inferring characteristics about underlying areas of deficit based on classification protocols derived from group studies.

7.2.6 The importance of articulatory feedback for the development of phonological representations

The final hypothesis examined was that a child with CCN would demonstrate inferior performance on the phonological representation tasks, phonological awareness, and early print decoding measures in comparison to younger children with typical speech development. Emma's poor performance on the PR judgment task suggested that her underlying phonological representations may not have been as well-specified as younger children with typical speech development. This finding was consistent with Smith's (2001) report of adults with CCN demonstrating inferior performance on a similar mispronunciation detection task in comparison with younger typically developing children. The performance by adults with severely limited speech output provided evidence for the importance of articulation skills in the development of underlying phonological representations (Vihman, 1982; Smith, 2001). Similarly, the finding is consistent with Foley and Pollastek's (1999) argument that an absence of good quality articulatory feedback limits the refinement of phonological representations in adolescents and adults with CCN.

Emma's comparatively strong performance on the phonological awareness measures suggested that she had access to some degree of segmental phonological representations, although her performance on these tasks was likely to be assisted by the task adaptations. Emma's word recognition ability was at a level similar to that expected for her cognitive development. Her difficulty on the adapted nonword reading task, however, suggested she was yet to utilise a phoneme-based word decoding strategy. Although children with CCN may develop some basic level of phonological awareness, development of phoneme-level awareness is likely to be challenging due to their limited feedback from both articulation and self-directed reading (Foley & Pollastek, 1999). Emma, therefore, is at high risk of future reading and spelling difficulties (Dahlgren-Sandberg & Hjelmquist, 1996a, 1996b; Vandervelden & Siegel, 1999).

7.2.7 Phonological representations within a connectionist model of lexical representation

Consideration of the processes and components of connectionist models of word recognition (Seidenberg & McClelland, 1989) provides theoretical insights into potential areas of difficulty that children with speech impairment experienced on the phonological representation tasks. The importance of gradual learning that takes place within connectionist networks through repeated exposure to stimuli highlight the developmental nature of phonological representations. Seidenberg and McClelland's (1989) model specified that in a mature network, individual words are represented by multiple units at different levels of representation, with each unit representing features of three consecutive speech sounds. For example, unit *a* might contain [fricative, vowel, stop] with a lower level unit *b* containing [labio-dental, back, velar]. Unique identification of the word *fog,* therefore, also requires activation of unit *c* containing [unvoiced, central, voiced]. Accordingly, multisyllable words, such as those presented as stimuli in the current study, will require the activation of multiple units to achieve recognition, and for speech production. Children with an immature network may not yet have access to all units for words, and are therefore likely to have difficulty judging the accuracy of words with isolated changes to vowel characteristics. The consistently inferior performance by children with speech impairment on the PR judgment task, suggests that as a group, they may not have access to the complete or correct combination of units for some words. Factors that may contribute to the poor specification of units for words include the negative feedback provided to their developing networks by speech impairment and degraded input from the environment (e.g., as a result of middle ear infection). Poor facilitative and inhibitory connections within a connectionist network are also likely to negatively influence the ability to judge, speak and reflect on sub-lexical components within words.

7.3 Summary of Findings

The findings reported in this thesis have validated the use of receptive tasks to investigate the development of phonological representations in young children. These tasks were able to identify group differences between children with and without speech impairment. Children with speech impairment were more likely to judge mispronounced real and nonword stimuli as correct productions. This indicated they may possess poor quality or indistinct phonological representations for the target words. The results provided additional support for Elbro's (1996) distinctness hypothesis for phonological representations. A weakness at the level of phonological representations is likely to negatively influence a child's ability to perform phonological awareness tasks, particularly those involving access to phoneme-level components (Elbro et al., 1998). Children who are able to access phonemes within words are more likely to develop superior reading skills compared to children who struggle to access phonemes (Hulme et al., 2002; McGuinness, 1997; Muter et al., 1997).

This study provides further evidence to support the importance of well-specified phonological representations to the development of phonological awareness and print decoding skills. Children with speech impairment demonstrated inferior performance on phoneme-level awareness tasks, indicating a difficulty in analysing segmental details within phonological representations. Performances on the experimental tasks, by children with and without speech impairment, also correlated moderately with performance on phonological awareness and print decoding tasks across the study. These findings are compatible with both the lexical restructuring (Walley, 1993) and segmentation hypotheses (Fowler, 1991) that emphasise the developmental nature of phonological representations. Children with speech impairment may possess holistic phonological representations that are capable of supporting improving or even accurate speech production, yet restrict children's development of phonological awareness skills (Swan & Goswami, 1997). These hypotheses state that vocabulary growth forces reorganisation of children's phonological representations that, in turn, leads to the availability of syllable, onset-rime, and eventually phoneme-level segments. In the current study, however, children with and without speech impairment were well-matched on receptive vocabulary at commencement of the study, yet some children with speech impairment demonstrated persistent difficulty on the phonological representation and phonological awareness measures. Thus indicating their phonological representations may not undergo the same restructuring or segmentation experienced by children with typical speech development. These findings support the hypothesis that some children with speech impairment share a similar underlying area of deficit with children who experience reading disability (Carroll & Snowling, 2004; Catts, 1986; Elbro et al., 1998; Swan & Goswami, 1997).

At the final assessment trial, several children with speech impairment appeared to be at risk of future reading disability. This was evident by their inability to decode printed nonwords or manipulate phonemes during phonological awareness tasks. Consistent with the modified critical age hypothesis (Nathan et al., 2004), the likelihood of these children experiencing difficulty acquiring reading skills was reinforced by the persistent nature of their speech difficulties (Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). Children in the current study, however, demonstrated a variety of speech, phonological awareness, and print decoding outcomes. The two children with the lowest PCC scores at trial 4 (i.e., 35% and 50%) performed poorly on phonological awareness and print decoding tasks. Similarly, two children who demonstrated strong improvement in speech skills by trial 4 (i.e., PCC > 85%), also performed poorly on these tasks. In contrast, two children produced PCC scores in excess of 85% at the final trial, and demonstrated superior phonological awareness and print decoding skills. These variable outcomes were evident despite children participating in speech therapy intervention and exposure to formal reading tuition. The reduction in correlation coefficients between speech and phonological representation measures, as the study progressed, suggested that improvement in speech production skills may not necessarily reflect a corresponding development in underlying phonological representations. This finding, together with the variability reported in the case studies of children with speech impairment ensures a need to carefully consider individual abilities before inferring information about children's underlying phonological representations.

7.4 Clinical Implications

The findings from this study have several implications for the assessment of preschool children with isolated speech impairment. The description of children's speech impairment, based on severity measures and detailed analyses of error pattern use, provide clinicians with appropriate speech intervention goals. These measures, however, are unlikely to present an accurate description of children's underlying storage of phonological information for words. To complement findings from speech production measures, clinicians should obtain information from receptive tasks that provide insight into children's phonological representations. Variants of the tasks described in this thesis are likely to provide such information. The use of large normative samples will, however, challenge the development of broad-spectrum clinical measures due to the need for appropriate local accents and dialectal stimuli. Nevertheless, clinicians could develop personal screening tasks using the presentation of live-voice stimuli similar to Carroll and Snowling's (2004) mispronunciation detection task. The current study has identified that fine-tuning the vowel segments within some multisyllable words to create stimuli, can provide clinicians with information on children's underlying phonological representations. The findings also reinforce the use well-specified assessment frameworks to document children's phonological processing skills. The psycholinguistic model described by Stackhouse and Wells (1997) provides a comprehensive and clinically-relevant framework within which to examine skills at different levels of the speech perception and production systems. This information will assist clinicians understanding of children's underlying phonological representations.

The findings further reinforce the need to investigate young children's phonological awareness, before they commence formal education. Several children with speech impairment demonstrated a weakness in their ability to analyse words at the phoneme-level during phonological awareness and print decoding tasks. At the first two assessment trials, children with speech impairment performed as well as control children at identifying syllables in words, performing rhyme oddity, and alliteration oddity tasks on the PIPA (Dodd et al., 2000). Group differences were, however, observed across the study on the phoneme segmentation and letter-sound knowledge subtests. Children's letter knowledge skills typically develop between 4- and 5-years-of-age and these skills have been shown to assist the emergence of phonological awareness (Burgess & Lonigan, 1998). Together, these skills are known to facilitate children's early word recognition development. Clinicians should, therefore, clearly document children's ability to demonstrate different levels of phonological awareness. Information on children's emerging phoneme-level awareness and letter-sound knowledge will assist the development of appropriate intervention plans.

Clinicians must consider the impact of therapeutic strategies on children's underlying phonological representations, in addition to speech production goals. Intervention targeting speech intelligibility in isolation may not insulate children from subtle deficits at the level of phonological representation, and subsequent phonological awareness and print decoding difficulties. The improvement in PCC scores recorded for children with speech impairment in the current study, suggested their phonological representations and/ or motor components of their speech output system were developing. Conversely, their inferior performance on the PR judgment and NW learning tasks, compared to children with typical speech development, indicated that they continued to struggle to reflect on phoneme-level components of their phonological representations. Gillon (2005) has clearly demonstrated that the integration of letter knowledge and phoneme-level awareness activities with therapy targeting speech sound development, can help 3- to 4-year-old children with severe speech impairment, successfully overcome speech production errors by age 6 and raise children's phonological awareness to the level of peers with typical speech development. Bryan and Howard (1992) also reported notable improvement in the speech production skills of a 5-year-old child after specific phonological awareness training. Determining the effectiveness of phonological awareness and reading-based intervention on improving the quality of children's underlying phonological representations, however, awaits further research. In the meantime, the evidence supports the inclusion of phonological awareness-based activities in intervention for children with severe speech impairment. Considering the developing body of evidence that has documented children with speech impairment experiencing reading difficulties, together with the importance of early environmental experiences, speech-language therapists must fulfil an advocacy role in ensuring children are exposed to optimal environmental stimuli at a young age. Gillon (2004) provides a range of examples of home-based activities designed to enhance early phonological awareness, in addition to a comprehensive instructional framework for the delivery of formal phonological awareness training. Clendon et al. (2005) also documented several intervention activities aimed at increasing phonological awareness of students with CCN. These skills are of critical importance for children and adults with CCN, who require reading and spelling skills to fully utilise the generative capabilities of modern high-tech AAC devices.

The study also provided anecdotal evidence to suggest intervention targeting speech production is effective in correcting children's speech sound errors. Strong gains were observed on PCC scores for several children with speech impairment during the study. Two children with delayed speech development made notable improvements in their speech sound production between trial 1 and 2, during the same period they received intervention. The plateau observed on PCC scores after trial 2, coincided with an absence of further speech therapy input. This pattern of performance is consistent with Gillon & Dodd's (1998) case study report of Ben's notable improvements in reading and spelling taking place during periods of intervention. This observation could also be explained by Shriberg, Gruber et al.'s (1994) report that preschool children with severe speech impairment experienced more rapid growth in speech sound production during specific age ranges (i.e., from ages 4 to 6 and 7 to 8.5 years). Shriberg, Gruber et al. (1994), however, did not report the relationship between these apparent windows of growth and the timing of speech therapy provided for children. Nevertheless, the findings from the current study suggest that some preschool children with severe speech impairment may struggle to achieve age appropriate speech production without ongoing intervention.

7.5 Limitations of the Study

The research design employed a clinical population with recruitment based upon speech-language therapists referring children with speech impairment to the study. This method, therefore, excluded randomised selection procedures for participants in the experimental group. To tighten homogeneity of the population sample, a range of exclusion criteria were established (e.g., PCC scores above 60%, and PPVT-III standard scores below 85). This procedure, however, limited the sample size to 9 children with speech impairment. This small group size reduced the statistical power of the correlational coefficients between variables across the study, and precluded the use of statistical techniques to determine the sensitivity of the experimental measures in estimating future phonological awareness and print decoding performance. Despite the design procedures to tighten homogeneity of the children with speech impairment, large within-group variation was evident during the study. This variability was highlighted by the small number of participants, and the superior phonological awareness and decoding skills displayed by the two eldest children with speech impairment. These children's performances undoubtedly inflated the group's mean scores on several measures. Nevertheless, significant between-group differences on phonological representation, phonological awareness, and letter-sound knowledge tasks were identified.

The PR judgment and NW learning tasks presented during the study were experimental and subject to limitations. Task presentation involved several assumptions about children's ability to complete these tasks. The main assumption was that the PR judgment task was able to tap into children's underlying phonological representations for the target words. The introduction of a control task to examine children's ability to perform a same-different judgment on correct and incorrect items would have helped to validate children's performance on the PR judgment task. However, prior to presentation of each PR judgment task, children were exposed to a picture naming task to ensure they were familiar with the target words. Similarly, the changes made to the presentation of the NW learning task may have influenced the task's validity. The reduction in training items across the study may have resulted in the task becoming more of a short-term phonological memory task. The continued presentation of six training slides (i.e., as at trial 1) at subsequent trials would have help to minimise possible interference effects of the initial judgment items. For example, if the first judgment item was a correct pronunciation, the child would be able to use this to further reinforce a new representation, whereas if the first judgment item was a mispronounced item, this may have had a detrimental effect on the new representation. This difficulty could also have been controlled for by adding further training slides together with a standard phonological distracter item prior to presentation of judgment items. Nevertheless, the experimental tasks used in this study provide insight into how some children with speech impairment have difficulty creating and accessing phonological representations. Further refinement of these tasks will ensure that clinicians are able to obtain precise information about children's storage of the phonological information that forms the basis for speech production.

7.6 Directions for Future Research

The research reported in this thesis provides several leads for future research. This includes the establishment of norm-referenced phonological representation tasks to provide clinicians with appropriate assessment tools. The normalisation process will require the presentation of tasks to a large number of children. Consideration of the local community's accent differences will be required to ensure stimuli are constructed using familiar pronunciations. Additionally, the introduction of stimuli using both familiar and unfamiliar speaker variables will build on our understanding of the nature of phonological representations. Investigation is also needed to determine if the difficulties children with speech impairment had in detecting mispronounced stimuli during the current study, continues when stimuli are based on more fine-grained acoustic changes to a wide variety of consonant sounds. This is particularly relevant considering the observations made during this study and clinical reports, that young children overcome vowel sound errors earlier than consonant errors. Broadening the range of stimuli used in the PR judgment task to include common and uncommon verbs and adjectives will also enhance our understanding of how children cognitively represent speech sound information associated with different word classes.

Longitudinal studies that begin observation of children earlier in childhood, and follow-up participants several years after school entry are needed to clarify the relationships between variables. These studies will develop knowledge of the links between early speech production and perception ability, and the development of phonological representations together with later reading and spelling development. The early commencement of monitoring children's speech development will also assist further description of different speech development pathways, and their relationship with underlying phonological representations. The observation that some children with unintelligible speech appear to use a high level of formulaic utterances (Peters, 1977), suggests the assumption that words are the initial basic unit of phonological representation may not hold for all children. Mehler et al. (1990) proposed that young children's cognitive templates used to develop phonological representations from continuous speech may be different from adults. For example, one phonological representation may contain several words. Young children typically use some speech formulae (Locke, 1983) (e.g., whole phrases or sentences), however, it is feasible that some children experience difficulty narrowing their focus of attention to the word level. These children may begin their segmentation (Fowler, 1991) and lexical restructuring (Walley, 1993) from a more gestalt level of processing, and therefore experience difficulty developing well-specified word-level representations. Further research is needed to determine if and to what extent children with speech impairment experience this phenomenon, and its effect on phonological representation development and the emergence of speech and phonological awareness skills.

Knowledge of the reciprocity of the relationship between phonological representations, phonological awareness, and early reading ability will be enhanced by further longitudinal studies. Of particular interest from the current study, is the ease with which children proceed to develop phoneme-based print decoding skills. This information will enhance our understanding of the trajectories of reading development among children with speech impairment. As phonological awareness and early reading development share a two-way relationship, it follows that emerging phonological awareness and reading skills will also enhance the quality of children's phonological representations. Longitudinal studies that control for the level and type of intervention provided for children with speech impairment will also provide information on the effectiveness of instructional activities at enhancing children's underlying representation of words. In particular, research is needed to determine whether the inclusion of phonological awareness activities facilitate the development of more precise and accessible phonological representations. This information will develop our ability to help children with speech impairment access phoneme-level information to facilitate their decoding of new and unfamiliar words.

7.7 Conclusion

This thesis has provided evidence to support a phonological representation deficit hypothesis for the phonological awareness and print decoding difficulties observed in some children who experience isolated speech impairment. These deficits were visible on novel receptive tasks requiring children to reflect on existing phonological representations, and create new representations. Children with speech impairment were more likely to incorrectly judge mispronounced multisyllable words as correct productions. These children also experienced difficulty identifying mispronounced examples of newly learned nonwords. At a group level, these findings indicated children with speech impairment were not as effective as children with typical speech development at integrating novel phonological information into stable representations, and reflecting on new and existing phonological representations. The group differences continued across the longitudinal study despite overall improvement in children's speech production skills. This indicated that some children were capable of producing accurate speech, yet did not have access to the segmental components of words. The difficulties that children with speech impairment experienced on phonological awareness measures that required phoneme-level knowledge, together with their difficulty in early print decoding tasks, indicated some of these children struggled to access the segmental components within words. These findings together with the correlations observed between variables across the study, reinforced the close relationship between children's representation of speech sounds in long-term memory, and their ability to use this information when developing print decoding skills.

The persistence and severity of several children's speech difficulties observed in the current study reinforced the need for the provision of early and ongoing intervention. The evidence reported suggested that although some children may present with relatively normalised speech production, underlying deficits at the level of phonological representations may remain and influence their ability to develop appropriate phonological awareness and print decoding skills. The heterogeneity of children with speech impairment highlighted the need for individualised assessment and intervention. This is especially important for children with CCN, who face added physical and social challenges in their development of effective written language skills. The provision of intervention that is proven to target both the accuracy of speech output and the quality of underlying phonological representations may well be identified as the optimal use of clinical resources. The findings reported in this thesis indicate that although phonological representations are a relatively abstract concept, they appear to be an important and valid construct to continue investigating, in an effort to determine specific characteristics of the storage and processing mechanisms involved in the development of speech, phonological awareness, and print decoding skills.

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Appendix A

Phonological Representation (PR) Judgment Task Word Lists

Trial 1

Instructions provided for children. "You will hear me say 'this is a telephone'. I want you to listen to how I say telephone. If I say it a good way – point to the happy face. If I say it not a good way – point to the cross." * = training items.

Word Gloss	Pronunciation	Type of Change
1. *Telephone	/tæləfoun/	typical
2. *Dinosaur	/dainəsɔ/	typical
3. *Motorbike	/mɜtaibouk/	change each vowel
4. *Hippopotamus	/hɪpɒtəmɪs/	delete unstressed syllable
5. *Caterpillar	/kætəpɪlə/	typical
6. Elephant	/ælfɪnt/	delete unstressed vowel
7. Kangaroo	/kæŋgəru/	typical
8. Helicopter	/hælaikɒptə/	change unstressed vowel
9. Telephone	/tælfoun/	delete unstressed vowel
10. Butterfly	/bʌtəflai/	typical
11. Caterpillar	/kautəpɪlə/	change stressed vowel
12. Motorbike	/meatəbaik/	change stressed vowel
13. Helicopter	/hælikɒptə/	typical
14. Dinosaur	/dainsɔ/	delete unstressed vowel
15. Caterpillar	/kætupɪlə/	change unstressed vowel
16. Elephant	/æləfɪnt/	typical
17. Kangaroo	/kæŋgauru/	change unstressed vowel
18. Butterfly	/bɒtəflai/	change stressed vowel
19. Elephant	/æloufɪnt/	change unstressed vowel
20. Motorbike	/moutibaik//	change unstressed vowel
21. Telephone	/touləfoun/	change stressed vowel
22. Kangaroo	/kæŋru/	delete unstressed syllable
23. Hippopotamus	/hɪpəpɒtəmɪs/	typical
24. Dinosaur	/dʌnəsɔ/	change stressed vowel
25. Hippopotamus	/hɪpɒtəmɪs/	delete unstressed vowel
26. Caterpillar	/kætpɪlə/	delete unstressed vowel
27. Butterfly	/bʌtuflai/	change unstressed vowel
28. Motorbike	/moutəbaik//	typical
29. Elephant	/ɜləfɪnt/	change stressed vowel
30. Motorbike	/moutbaik/	delete unstressed vowel

Trial 2

Instructions provided to children "You will hear me say the word 'crocodile'. I want you to listen to how I say telephone. If I say it a good way or the right way – point to the green tick. If I say it a wrong way or not quite the right way – point to the red cross. Even if you think it's nearly the right way – point to the red cross." * = training items.

Word Gloss	Pronunciation	Type of Change
1. *Crocodile	/krɒkədail/	typical production
2. *Giraffe	/dʒɪrif/	change stressed vowel
3. *Computer	/kɪmpjutə/	typical production
4. *Spaceship	/spaisʃɪp/	change stressed vowel
5. *Monster	/mɒnstə/	typical production
6. Hospital	/hɒstɪpɪl/	common speech production error
7. Toaster	/tɒstə/	change unstressed vowel
8. Ambulance	/æmbjulɪns/	typical production
9. Monster	/mounstə/	change stressed vowel
10. Computer	/kimpjutə/	change unstressed vowel
11. Crocodile	/krɒkədail/	typical production
12. Spaceship	/speisʃɪp/	typical production
13. Caterpillar	/kautəpɪlə/	change stressed vowel
14. Banana	/bɪnanə/	typical production
15. Giraffe	/dʒɪraf/	typical production
16. Hospital	/haspɪtɪl/	change stressed vowel
17. Ambulance	/æmbliɪns/	common speech production error
18. Butterfly	/bɒtəflai/	change stressed vowel
19. Monster	/mɒnstə/	typical production
20. Caterpillar	/kætaipɪlə/	change unstressed vowel
21. Garage	/gærɪdʒ/	typical production
22. Crocodile	/krɒkədeil/	change stressed vowel
23. Computer	/kɪmpjutə/	typical production
24. Kangaroo	/kæŋru/	delete unstressed syllable
25. Ambulance	/æmbjulans/	change unstressed syllable
26. Spaceship	/speisʃɒp/	change stressed syllable
27. Banana	/bɪnanə/	typical production
28. Toaster	/taustə/	change stressed vowel
29. Hospital	/hɒspɪtɪl/	typical production
30. Garage	/gærudʒ/	change unstressed vowel

Trial 3

Instructions provided to children were the same as trial 2.

Word Gloss		Pronunciation	Type of Change
1.	*Crocodile	/krɒkədail/	change stressed vowel
2.	*Computer	/kɪmpjutə/	typical production
3.	*Spaceship	/spaiʃɪp/	change stressed vowel
4.	Monster	/mɒnstə/	typical production
5.	Spaghetti	/spægɒti/	change stressed vowel
6.	Ambulance	/æmbjəlɪns/	typical production
7.	Gorilla	/gɔrelə/	change unstressed vowel
8.	Caterpillar	/kætəpɪlə/	typical production
9.	Giraffe	/dʒɪrɒf/	change stressed vowel
10.	Helicopter	/helikɒptə/	typical production
11.	Hamburger	/hæmbeigə/	change stressed vowel
12.	Microphone	/maikrʊfoun/	change unstressed vowel
13.	Caterpillar	/kætaipɪlə/	change unstressed vowel
14.	Spaghetti	/spægeti/	typical production
15.	Hamburger	/hæmbɒgə/	change stressed vowel
16.	Helicopter	/helakɒptə/	change unstressed vowel
17.	Monster	/mounstə/	change stressed vowel
18.	Giraffe	/dʒuraf/	change unstressed vowel
19.	Microphone	/maikrəfoun/	typical production
20.	Gorilla	/gɔreilə/	change unstressed vowel
21.	Spaghetti	/pɪzgeti/	common speech production error
22.	Ambulance	/ambjulɪns/	change stressed vowel
23.	Hamburger	/hæmbɜgə/	typical production
24.	Helicopter	/helikɒptə/	typical production
25.	Monster	/mʌnstə/	change stressed vowel
26.	Giraffe	/dʒairaf/	change unstressed vowel
27.	Caterpillar	/kætoupɪlə/	change unstressed vowel
28.	Microphone	/maikrifoun/	change unstressed vowel

Trial 4

These stimuli were presented on two separate tasks, one with pictures and one without pictures.

Instructions provided to children were the same as trial 2.

Word Gloss		Pronunciation	Type of Change
1.	*Lemonade	/lemɪneid/	typical production
2.	*Camera	/kæmrə/	typical production
3.	*Aeroplane	/eraiplein/	change unstressed vowel
4.	Waterfall	/wɔtəfɔl/	typical production
5.	Octopus	/ɒkdɔpʊs/	change unstressed vowel
6.	Bulldozer	/bʊldaizə/	change stressed vowel
7.	Octopus	/ɒkdəpʊs/	typical production
8.	Bumblebee	/bʌmbʌlbi/	typical production
9.	Parachute	/pærouʃut/	change unstressed vowel
10.	Bulldozer	/bʊldouzə/	typical production
11.	Tomato	/təmoutou/	change stressed vowel
12.	Policeman	/pəlismæn/	typical production
13.	Lemonade	/lemɒneid/	change unstressed vowel
14.	Tomato	/təmatou/	typical production
15.	Rhinoceros	/rainɒsərɪs/	typical production
16.	Dragonfly	/dræginflai/	change unstressed vowel
17.	Waterfall	/wɔtifɔl/	change unstressed vowel
18.	Sunglasses	/sʌnglasɪz/	typical production
19.	Policeman	/pəlusmæn/	change stressed vowel
20.	Octopus	/ɒkdaipʊs	change unstressed vowel
21.	Dragonfly	/drægɒnflai/	change unstressed vowel
22.	Parachute	/pæriʃut/	change unstressed vowel
23.	Tomato	/təmaitou/	change stressed vowel
24.	Strawberry	/straberi/	change stressed vowel
25.	Television	/teləvɪʒɪn/	typical production
26.	Dragonfly	/drægɪnflai/	typical production
27.	Strawberry	/strɔbri/	typical production
28.	Parachute	/pærəʃut/	typical production

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Trial 4: Frequency – Density Stimuli Variations

Instructions provided to children were the same as other PR Judgment tasks at trial 4.

Word Gloss	Pronunciation	Type of Stimuli
1. *Head	/hed/	correct - high - dense
2. *Toad	/tɒd/	incorrect - low - sparse
3. *Leash	/leʃ/	incorrect - low - sparse
4. Dog	/dɒg/	correct - high - sparse
5. Head	/hid/	incorrect - high - dense
6. Bag	/bag/	incorrect - high - dense
7. Mug	/mʌg/	correct - low - dense
8. Church	/tʃutʃ/	incorrect - high - sparse
9. Leash	/liʃ/	correct - low - sparse
10. Dirt	/dɔt/	incorrect - high - sparse
11. Dog	/dʌg/	incorrect - high - sparse
12. Leash	/lɪʃ/	incorrect - low - sparse
13. Comb	/kʌm/	incorrect - low - dense
14. Toad	/toud/	correct - low - sparse
15. Mug	/mɒg/	incorrect - low - dense
16. Church	/tʃɒtʃ/	incorrect - high - sparse
17. Bag	/bæg/	correct - high - dense
18. Vet	/væt/	incorrect - low - dense
19. Mole	/mʌl/	incorrect - low - sparse
20. Dirt	/dɛt/	correct - high - sparse
21. Bag	/bɒg/	incorrect - high - dense
22. Toad	/tud/	incorrect - low - sparse
23. Dirt	/dat/	incorrect - high - sparse
24. Mole	/moul/	correct - low - sparse
25. Head	/hɪd/	incorrect - high - dense
26. Comb	/koum/	correct - low - dense
27. Dog	/dɔg/	incorrect - high - sparse
28. Comb	/kɒm/	incorrect - low - dense

Appendix B

Nonword Learning Stimuli Lists

Instructions provided for children. "We are going to learn some new words. First you will see pictures of the word and hear me say the name of the word. After you have learned about the word you will see and hear the word again. This time you will need to show me if the word is said the right way or a wrong way. If it is right, point to the green tick. If it is wrong, point to the red cross."

Trial 1

Target Nonwords	Transcription of each task item
1. /blaig/ (training item)	/blaig/, /flaig/, /blaig/, /blæg/.
2. /gwɔimz/	/gwɔimz/, /gwɔmz/, /gwʌmz/, /gwɔimz/.
3. /mælətʃed/	/mælətʃep/, /mæləʃed/, /mælətʃed/, /mæloutʃed/.
4. /krepdislʌv/	/krepdislʌv/, /krepdislʌv/, /krɒpdislʌv/, /kredislʌv/.
5. /tʃɜfout/	/tʃifout/, /tʃɜfout/, /tʃɜfʊt/, /tʃɜfoug/.
6. /kʊstɒn/	/kʊstɒn/, /kʊstbip/, /kʊstɒn/, /kʊftɒn/.

Trial 2

Instructions provided for children "We are going to learn some new words. First you will see pictures of the word and hear me say the name of the word. After you have learned about the word you will see and hear the word again. This time you will need to show me if the word is said the right way or a wrong way. If it is right, point to the green tick. If it is wrong, point to the red cross. Even if you think the word is not quite right point to the red cross."

Target Nonwords	Transcription of each task item
1. /glaim/ (training item)	/glaim/, /glam/, /glaim/, /glæm/.
2. /dʒɜgz/	/dʒegz/, /dʒugz/, /dʒɜgz/, /dʒɜgz/.
3. /bæzdətʃoud/	/bæzdətʃʊd/, /bæzdətʃoud/, /bazdətʃoud/, /bizdətʃoud/
4. /trɒknifaiʃ/	/trɒknifeiʃ/, /trɒknifaiʃ/, /trɒknifaiʃ/, /trʌknifaiʃ/.
5. /hɔipənɜb/	/hɔpənɜb/, /hɔipɔnɜb/, /hɔipənɜb/, /hɔipənɜb/.
6. /wʊtauzɪn/	/wʊtauzɪn/, /wʌtauzɪn/, /wʊtazɪn/, /wʊtauzɪn/.

Trial 3

Target Nonwords	**Transcription of each task item**
1. /ʃɜkoufaim/ (training item)	/ʃɜkoufaim/, /ʃɜkɒfaim/, /ʃɜkoufaim/, /ʃɜkifaim/.
2. /tʊpaunɜg/	/tɜpaunɜg/, /tʊpaunɜg/¸ /tʊpanɜg/, /tʊpaunɜg/.
3. /fɔirælɪb/	/fɔirelɪb/, /fɔirælɪb/¸ /fɔirælab/, /fɔirælɪb/.
4. /pɒdʒrɪni/	/pɒdʒræni/, /pɒdʒrɒni/, /pɒdʒrɒni/, /pɒdʒrɪni/.
5. /tʃɒvludɪn/	/tʃɒvludɪn/, /tʃɒvlɒdɪn/, /tʃɒvlʌdɪn/¸ /tʃɒvlɒdɪn/.
6. /fleŋgiʃʌm/	/fleŋgəʃʌm/, /fleŋgiʃʌm/, /fleŋgʊʃʌm/, /fleŋgəʃʌm/.

Trial 4

Target Nonwords	**Transcription of each task item**
1. /grædfɔz/ (training item)	/grʌdfɔz/, /grædfɔz/, /grædfʌz/, /grædfɔz/.
2. /plɒnwatsi/	/plɒnwatsi/, /plɒnwɒtsi/¸ /plænwatsi/, /plɒnwatsi/.
3. /jʌŋgəsɔnbi/	/jʌŋgusɔnbi/, /jʌŋgəsɔnbi/, /jʌŋgəsɔnbi/, /jʌŋgəsʌnbi/.
4. /hekəmaiʃti/	/hekumaiʃti/, /hekəmaiʃti/.
5. /dʒidəʃeb/	/dʒidiʃeb/, /dʒidəʃeb/, /dʒidaʃeb/, /dʒidəʃeb/.
6. /sprɪmitʃeid/	/sprɪmetʃeid/, /sprɪmitʃed/, /sprɪmitʃeid/, /sprɪmetʃeid/

Appendix C

Receptive Gating Task Word List – Trial 1 only

Instructions provided for children. “You will hear me say the very first part of a word. I want you to point to the picture for the word you think I am trying to say.”

Word list	Length of stimulus (ms)
1. Book*	200
2. Bed*	200
3. sheep*	250
4. Cup	150
5. Fish	290
6. light	260
7. shark	240
8. spoon	400
9. Dog	130
10. cheese	200
11. clock	170
12. map	210
13. Fish	340
14. light	310
15. shark	290
16. clock	220
17. Cup	200
18. Dog	180
19. cheese	250
20. map	260
21. spoon	450
22. Cup	250
23. map	310
24. spoon	500
25. light	410
26. shark	340
27. Fish	440
28. clock	320
29. Dog	230
30. cheese	300

Appendix D

Real and Nonword Repetition Task Word List

Real Word Stimuli presented at each trial.

Gymnasium	Helicopter	Ambulance	Volcano	Stopwatch
Asteroid	Frozen	Hospital	Australia	Kindergarten

Trial 1 - Nonword Stimuli

Gloss	Phonetic Transcription
1. Steyboose	/steibus/
2. Flowdarshay	/floudaʃei/
3. Kazartog	/kəzatɒg/
4. Munobleem	/mʌnoublim/
5. Snaipouseedy	/snaipousidi/
6. Nookloudayshot	/nʊkloudeiʃɒt/
7. Chickoufer	/tʃɪkoufɜ/
8. Rangafayjop	/ræŋgəfeidʒɒp/
9. Wigenzord	/wɪgɪnzɔd/
10. Yomwadgi	/jɒmwadʒi/

Trial 2

Gloss	Phonetic Transcription
1. stoufoodeykep	/stoufudeikep/
2. pauzemunt	/pauzəmʌnt/
3. vathernog	/vaθɜnɒg/
4. chengooplim	/tʃeŋuplɪm/
5. ruzfeewikle	/rʌzfiwɪkʊ/
6. dershoucromp	/dɜʃoukrɒmp/
7. straleespenook	/strælispenʊk/
8. gromlermnep	/grɒmlɜmnep/
9. clouseihup	/klouseihʌp/
10. yawjoovain	/jɔdʒuvain/

Trial 3

Gloss		Phonetic Transcription
1.	cherpleedek	/tʃɜplidek/
2.	maglefaut	/magləfaut/
3.	weamzugri	/wimzugri/
4.	shonggurnfrad	/ʃɒŋgɜnfræd/
5.	tusgerbiv	/tʌsdʒɜbɪv/
6.	koospraiduti	/kuspraidʌti/
7.	naizungflaikrep	/naizʌŋflaikrep/
8.	yeedimprog	/jidɪmprɒg/
9.	horlibrenswid	/hɔlibreswɪd/
10.	tuckooyamwidgee	/tʌkujæmwɪdʒi/

Appendix E

Phonological Awareness Probe descriptions

These phonological awareness probe tasks were presented at trial 2, 3, and 4. Refer to Stahl and Murray (1994) for complete descriptions.

1a. Phoneme Isolation (initial phonemes)

The instructions presented to children were: "I want you to listen for just one sound in a word. Tell me the sound you hear at the beginning of each word I say. For example if I say *fix*, you say */f/*."

Training items: no, ship, time, hot, jump.

Stimuli: food, came, side, pad, seal, flood, cross, speak, please, state.

1b. Phoneme Isolation (final phonemes)

The instructions presented to children were: "Now I want you to listen and tell me the sound at the very end of each word I say. For example if I say *watch*, you say /*ch*/."

Training items: off, fish, egg.

Stimuli: room, not, gas, sled, cross, sand, junk, limp, build, best.

2. Phoneme Blending

The instructions presented to children were: "I'm going to say some words in a secret code, spreading out the sounds until they come out one at a time. Guess what word I'm saying. For example if I say /h/ - /ae/ - /m/, you say *ham*."

Training items: fun, king, some, send.

Stimuli: map, ten, set, did, sheep, flat, crack, space, plain, step, find, pink, camp, wild, last.

3. Phoneme Segmentation

The instructions presented to children were: "Do you remember when I said the words in a secret code and you guessed what word I was saying? This time I want you to say the word in a secret code. I'll say the word and you spread out all the sounds in the word. For example, if I say *sheep*, you say /sh/ - /ee/ - /p/."

Training items: me, fish, can, sand, ash.

Stimuli: move, time, sick, done, soup, float, cream, speed, place, stick, send, think, ramp, sold, toast.

4a. Phoneme Deletion (initial phonemes)

The instructions presented to children were: “I wonder if you could take a sound away from a word and make a whole new word. For example, say *meat*. Now say it again but don’t say /m/.” Each item was presented with the carrier phrase “Say ____, now say it again, but don’t say ___”.

Training items (stimuli and target): make (ache), learn (earn).

Stimuli: face (ace), kin (in), sat (at), page (age), sand (and), flight (light), crash (rash), spot (pot), plug (lug), stone (tone).

4b. Phoneme Deletion (final phonemes)

The instructions presented to children were: “Now listen for the sound at the end of the word”. Each item was again presented with the carrier phrase “Say ____, now say it again, but don’t say ___”.

Training items (stimuli and target): keep (key), pail (pay).

Stimuli: lime (lie), might (my), race (ray), need (knee), rice (rye), tend (ten), sink (sing), bump (bum), hold (hole), paste (pace).

Appendix F

Burt Word Reading Test Items and Distracter Stimuli

The following stimuli were presented to the child with CCN using a receptive-based adaptation of test.

Target Word	Distracter Items
1. to	tu, ti
2. is	iz, it
3. up	ud, ut
4. for	fur, fer
5. big	bug, bid
6. he	hi, hie
7. at	aet, et
8. one	on, wun
9. my	mi, mai
10. sun	sin, sen
11. went	wend, want
12. girl	gerl, gir
13. boys	boy, borz
14. day	dhay, dei
15. son	some, sime
16. his	hiz, hes
17. that	fat, thet
18. of	ov, off
19. an	en, aen
20. wet	whet, weet
21. love	luv, lave
22. water	woter, weter
23. no	now, noo
24. just	jus, jest
25. put	poot, pot
26. or	oars, aw
27. now	naw, noo
28. things	fings, thins
29. told	toal, told
30. sad	sud, sed
31. carry	chari, kerry
32. village	valliage, villain
33. quickly	quickly, quill
34. nurse	noose, nurts
35. beware	beewear, because
36. return	retry, ritern
37. scramble	scrabble, scribbs
38. twisted	twisty, tweeted
39. journey	jurnee, journal
40. luncheon	lunch, linchin

Appendix G

Nonword Reading Task Stimuli

This task was presented at trial 3 only. The instructions presented to children. "Here are some words. They are made-up words. I want you to try and read them for me."

Word presented	Correct response (Transcription)	Distracter items used on receptive version*
1. vab	/væb/	vub, vabe
2. kos	/kɒs/	koz, kose
3. sim	/sɪm/	sum, sime
4. dup	/dʌp/	doup, dupe
5. mov	/mɒv/	mouv, moov
6. tob	/tɒb/	tobe, toob
7. zug	/zʌg/	zig, zog
8. hud	/hʌd/	houd, hude
9. tiz	/tɪz/	tez, tyz
10. sep	/sep/	seep, sip
11. plob	/plɒb/	plub, plobe
12. bling	/blɪŋ/	blinge, bleng
13. bruch	/brʌtʃ/	brush, bruche
14. trock	/trɒk/	truck, trocke
15. twud	/twʌd/	twude, twod
16. cliz	/klɪz/	cleiz, clize
17. thrad	/θræd/	thread, thade
18. whan	/wæn/	whane, whean
19. gluff	/glʌf/	gloff, glueff
20. swek	/swek/	sweek, swik
21. feen	/fin/	fein, fen
22. poy	/pɔi/	poey, poe
23. zie	/zai/	zyi, zay
24. hoob	/hub/	hobe, hube
25. yoat	/jout/	yoot, yate
26. mape	/meip/	map, mep
27. roit	/rɔit/	royit, riot
28. gice	/gais/	geyes, gece
29. pute	/put/ or /pjut/	put, poote
30. lawp	/lɔp/	loop, loip

*receptive version presented to participant with complex communication needs only.