

School of Psychology and Speech Pathology

**Phonological processing skills in children with Specific Language
Impairment.**

Mary Elizabeth Claessen

This thesis is presented for the Degree of

Doctor of Philosophy

of

Curtin University

February 2013

Declaration by Author

“To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.”

Abstract

There is much debate in the literature about the cause, presentation, diagnosis and treatment of specific language impairment (SLI). Research has been hampered by the heterogeneity evident within the diagnostic group as well as a paucity of tasks to measure specific skills and thus increase our understanding of the underlying deficit. One prominent theory is that children with SLI have an underlying deficit with phonological processing skills although the role of phonology in the establishment of accurate, well specified phonological representations is still unclear.

This program of research aimed to add to the body of evidence by addressing these key methodological issues and exploring the phonological processing skills of children with SLI. In the initial phase of the research, two silent measures of phonological representations were designed and developed to fill a recognised gap. The Quality of Phonological Representations task aims to explore the accuracy of a child's stored phonological representation of a multisyllabic word. The Silent Deletion of Phonemes task aims to explore how well specified a stored phonological representation is, and requires a child to perform a silent deletion task on a stored phonological representation.

The Quality of Phonological Representations and Silent Deletion Of Phonemes were then used as part of a comprehensive battery of phonological processing measures to explore the phonological processing skills of a well-defined group of children with SLI (n=21), typically developing children matched for age (n=21) and typically developing children matched for receptive language skills (n=21). The task battery

also included measures of phonological awareness, short-term and working memory and rapid automatized naming.

Children with SLI had generally weaker phonological processing skills than typically developing children matched for age. The profile was more varied when compared to typically developing children matched for language. Despite employing tight selection criteria, there was a wider spread of scores for children with SLI than for typically developing peers. The children with SLI demonstrated weaker performance on both short-term and working memory tasks, as well as a measure of quality of phonological representations.

Overall, the children with SLI demonstrated an interesting pattern of phonological processing skills, with particular difficulty observed in phonological and working memory. Children with SLI also evidenced lower quality stored phonological representations of multisyllabic words. Performance on measures of phonological awareness was strong indicating that such skills can be taught, but that improvement in this area does not necessarily improve the quality of the underlying phonological representation.

The research provided some support for a specific processing account of SLI. It also highlighted the importance of phonological and working memory in the development of accurate phonological representations.

Acknowledgements

Firstly to my supervisors, Suze Leitão and Cori Williams, thankyou for your support throughout the journey. Both of you have provided encouragement and support throughout my PhD studies, as supervisors, colleagues, and friends. You have both shared the ups and downs of the journey.

Thankyou to Nick Barrett and Bob Kane who have provided support with statistical analysis along the way. To John Hogben, the phonological representations tasks would not have come to fruition without your contribution and support in the early stages of my research.

To Professor Jan Piek, thankyou for your support and guidance throughout the journey. From the time I expressed an interest in undertaking research, you have offered your support and encouragement.

Thankyou to the children, and their families, who gave their time so generously at each stage of the project. And to the principals and teachers who welcomed me into their schools and helped with recruiting participants. And a special thankyou my former colleagues at Fremantle Language Development Centre who were so generous with their time and support in the data collection phase of my research. Working with you and the children at the LDC inspired me to complete this program of research.

To staff at the School of Psychology and Speech Pathology, thankyou for your words of encouragement and support. There are so many of you who have expressed an interest in my project, and enquired about progress. I feel really honoured to work within such a supportive environment.

And finally to my family, thank you for the support you have given me, throughout this long journey. Each of you has been so patient through each phase from the initial literature searching, through data collection, and the waiting to hear back from journal editors.

List of publications incorporated into the thesis

The following peer-reviewed publications have been incorporated into the thesis:

1. Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language & Communication Disorders*, 44(2), 121-144.
2. Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language and Communication Disorders*, 45(4), 411-423.
3. Claessen, M. & Leitão, S. (2012) Phonological representations in children with SLI. *Child Language Teaching and Therapy*, 28 (2), 211-224.
4. Claessen, M., Leitão, S., Kane, R. & Williams, C. (in press) Phonological processing skills in Specific Language Impairment. *International Journal of Speech-Language Pathology*
5. Claessen, M. and Leitão, S. (2012) The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14 (3) 226-234.

“I warrant that I have obtained, where necessary, permission from the copyright owners to use any third-party copyright material reproduced in the thesis (e.g. questionnaires, artwork, unpublished letters), or to use any of my own published work (e.g. journal articles) in which the copyright is held by another party (e.g. publisher, co-author).”

Statement of contribution of others

1. Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009).

Quality of phonological representations: A window into the lexicon?

International Journal of Language & Communication Disorders, 44(2),
121-144.

Claessen was responsible for design and development of the Quality of Phonological Representations Task, and contributing to the literature review, data analysis, and drafting and writing the article. Heath, Fletcher, Hogben and Leitão contributed to the concept and design of the study, drafting and writing the article and with data analysis and interpretation.

2. Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language and Communication Disorders*, 45(4), 411-423.

Claessen was responsible for design and development of the Silent Deletion of Phonemes Task, participant recruitment, data collection and interpretation, reviewing the literature and drafting and writing the article. Leitão contributed to the concept and design of the study and with reviewing drafts of writing. Barrett was responsible for providing support with the data analysis.

3. Claessen, M. & Leitão, S. (2012) Phonological representations in children with SLI. *Child Language Teaching and Therapy*, 28 (2), 211-224

Claessen was responsible for developing the concept and design of the study, participant recruitment, data collection, analysis and interpretation, reviewing the literature and drafting and writing the article. Leitão contributed to the concept and design of the study and with reviewing drafts of the article.

4. Claessen, M., Leitão, S., Kane, R. & Williams, C. (in press)
Phonological processing skills in Specific Language Impairment

Claessen was responsible for developing the concept and design of the study, participant recruitment, data collection, analysis and interpretation, reviewing the literature and drafting and writing the article. Leitão & Williams contributed to the concept and design of the study and with reviewing drafts of writing. Kane provided support with data analysis and editing.

5. Claessen, M. and Leitão, S. (2012) The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14 (3) 226-234

Claessen was responsible for developing the concept and design of the study, participant recruitment, data collection analysis and interpretation, reviewing the literature and drafting and writing the article. Leitão contributed to the concept and design of the study and with reviewing drafts of the article.

Mary Claessen

Suze Leitão

Cori Williams

PhD candidate

Supervisor

Supervisor

A written statement from each of the co-authors of papers is included as Appendix 1.

Additional publications by the candidate relevant to the thesis but not forming part of it

Podcast

1. Claessen, M. & Leitão, S. (2012). *Phonological representations in children with SLI*. Child Language Teaching and Therapy Podcast
4. http://clt.sagepub.com/site/Podcast/podcast_dir.xhtml

Non peer-reviewed publication

1. Heath, S., Claessen., Fletcher, J., Leitão, S and Hogben, J. (2006). *Rapid automatized naming (RAN): A separate influence on literacy outcomes*. Learning Difficulties Australia Bulletin 38 (1), 12-14.

Oral presentations

1. Claessen, M. & Leitão, S. (2011). *Underlying phonological representations in children with SLI language impairment: judgment and production of multisyllabic words*. Paper presented at the Speech Pathology Australia National Conference, Adelaide, SA.
2. Claessen, M., Leitão, S., Heath, S., Hogben, J., & Fletcher, J. (2006). *Exploring phonological representations: MSW judgment in children with SLI*. Paper presented at the Speech Pathology Australia National Conference, Fremantle, WA.

3. Claessen, M., Leitão, S., Heath, S. & Hogben, S. (2005). *Phonological representations: a window into the lexicon*. Invited seminar presented for Language Development Centre staff, Perth.

4. Claessen, M., & Leitão, S. (2004). *Phonological representations: a window into the lexicon*. Paper presented at the 26th World Congress of the International Association of Logopedics and Phoniatrics, Queensland.

5. Heath, S., Claessen, M., Fletcher, J., Hogben, J., & Leitao, S. (2006). *Catch them before they fall: Cost effective identification of students at-risk for literacy problems*. Paper presented at the Speech Pathology Australia National Conference, Fremantle, Western Australia.

6. Leitão, S. & Claessen, M. (2011). *The development of multisyllabic word naming: When do binocliars become binoculars?* Paper presented at the Speech Pathology Australia National Conference, Adelaide, SA.

Table of contents

Title	Page
Introduction and overview	14
Paper 1	36
Paper 2	61
Paper 3	75
Paper 4	89
Paper 5	103
General discussion	108
Appendices	129
Bibliography	151

Introduction

Specific Language Impairment (SLI) is a term used to describe a significant impairment in language ability in the absence of hearing impairment, general developmental delay, neurological impairment or autism (Schwartz, 2009). Children with SLI form a heterogeneous group with a reported prevalence of 7% (Leonard, 1998).

There is much debate in the literature about the cause, presentation, diagnosis and treatment of specific language impairment (SLI). Research has been hampered by the heterogeneity evidenced within the diagnostic group with debate in the literature about the severity and extent of language impairment required for SLI to be diagnosed. The role of performance IQ in diagnosis has also been controversial with many researchers suggesting that measurement of performance IQ is required to distinguish between SLI and a more general delay (Bishop, 1997; Schwartz, 2009), and other researchers suggesting diagnosis be made on the basis of comparison of language skills with age-matched peers (Schwartz 2009). There are a number of issues in making a diagnosis on the basis of such comparisons. Standardized tests have recognised errors of measurement and comparing scores, in this way exacerbates such errors. In addition using a measure of performance IQ in diagnosis raises social issues of provision of services in terms of both models and funding (Leonard 1998). The challenges in diagnosis and treatment of SLI are exacerbated by the paucity of tasks available to measure specific skills and therefore both support identification and our understanding of the underlying factors that contribute to the impairment.

A number of theories have been proposed to explain the underlying deficit in SLI. These have been broadly categorized into linguistic (grammatical) theories, and cognitive (processing) theories. Grammatical accounts all propose that SLI involves impaired grammar however they vary on the exact nature of the grammatical deficit, the relative frequency of grammatical deficits, and whether other aspects of language are also impaired (Rice & Wexler, 1996; Van der Lely, Rosen, & McClelland, 1998). In addition to grammatical deficits however, children with SLI have been reported to exhibit difficulties in a range of areas such as working memory, speech perception, and analogical reasoning (Aguilar-Mediavella, Sanz-Torrent, & Serra-Raventos, 2002; Van der Lely et al., 1998). As a consequence, researchers have proposed that the deficits observed in SLI may be the result of a limitation in information processing capacity rather than a specific grammatical deficit (Leonard, 1998).

Processing accounts can be grouped into those that presume there is a generalized deficit in processing capacity (Ellis Weismer, Evans, & Hesketh, 1999; Miller, Kail, & Tomblin, 2001), and those that presume that a deficit in a specific processing mechanism is responsible for the language impairment (Gathercole & Baddeley, 1990). Generalised processing theories suggest that children with SLI have a limited capacity of resources available for information processing and storage. Miller et al. (2001) demonstrated that children with SLI evidenced slower processing than typically developing peers across a range of linguistic and nonlinguistic tasks. Ellis Weismer et al. (1999) also found support for this theory with their finding that children with SLI demonstrated greater deficits in working memory than normal language peers. In light of these findings, Leonard et al. (2007) more recently

suggested that generalised processing deficits may be further broken down into deficits in processing capacity or processing speed. Deficits in processing capacity may be the result of restricted space to process information, or restricted energy available for processing information and is usually measured with tasks assessing short term and working memory. Deficits in processing speed are often measured using reaction time tasks.

In contrast to general language processing limitations, there have been a number of theories which have proposed a limitation in a specific area of processing. These arose from the observation that children with SLI have difficulty processing brief auditory stimuli and stimuli presented in rapid succession (Leonard, 1998). This finding suggests that impaired perception of speech may interfere with the development of phonological representations, which in turn affects other aspects of language including grammatical development.

One example of a specific processing theory is the proposal that children with SLI have weak *phonological* processing skills which impacts on their ability to encode, develop, maintain, store and access well-specified phonological representations. It has been suggested (Joanisse & Seidenberg, 1998) that this deficit results in the widespread difficulties observed in children with SLI, including difficulties with grammar. For example, errors with past tense forms may be explained within this theory as a difficulty storing or accessing a poorly specified phonological representation for the morphemes.

Chiat (2001) proposed that the widespread impairment in language observed in SLI, characterized by difficulties such as marking past tense, repeating nonwords and with phonological awareness tasks might be explained by impaired phonological processing skills that disrupt the mapping of phonological form onto meaning.

Mapping theory proposes that in order to learn language, children must segment the incoming speech stream into individual words and morphemes, and with the support of context, attach meaning to these segments (Chiat, 2001). While the child uses prosodic cues to distinguish word boundaries they must then use context to make a connection between the sounds they hear and the referent. Chiat (2000) notes that children as young as nine months are able to point to a familiar item when named, and to perform rehearsed actions such as clapping when asked. This indicates that even prior to the emergence of single words typically developing children are able to map between phonology and semantics as language develops.

The role of phonology in each of the specific processing theories above leads to the suggestion that a weakness in the ability to process sound based information is at the core of SLI. Therefore, in order to explore this further, it is vital that we develop an understanding of how phonological information is processed.

Phonological processing

An early attempt to describe phonological processing is that presented by Wagner and Torgesen (1987) who defined phonological processing as “the use of phonological information in processing written and oral language” (Wagner & Torgesen, 1987, p.192). In their framework, Wagner and Torgesen describe three separate constructs which they combine into a core concept of phonological processing skills:

phonological awareness, phonetic coding in working memory and phonological recoding in lexical access. Phonological awareness is “explicit awareness of the phonological structure of the words in one’s language” (Torgesen, Wagner, & Rashotte, 1994, p. 276). Phonetic coding in working memory refers to the ability to code the phonological features of language in memory (Torgesen et al., 1994). Phonetic recoding in lexical access is the rapid retrieval of phonological codes from the lexicon and is often measured using rapid automatized naming tasks (Torgesen et al., 1994).

Phonological awareness and phonological representations are two closely related concepts. The concept of a phonological representation is an abstract one; however the term has been widely used to explain the storage of phonological information in long-term memory (Sutherland & Gillon, 2005). Given that phonological awareness allows a child to be aware of and reflect on the structure of a spoken word it can be considered the ability to reflect on the structure of phonological representations.

Many researchers have studied the phonological processing skills of children with SLI within the constructs described by Wagner and Torgesen (Torgesen et al 1994). It has been consistently reported that children with SLI have significantly poorer performance on phonological awareness tasks than typically developing peers (Vanderwalle, Boets, Ghesquiere, & Zink, 2010). Children with SLI have also been found to have difficulty with tasks that assess phonological memory, such as nonword repetition (Archibald & Gathercole, 2006; Botting & Conti-Ramsden, 2001; Ellis Weismer et al., 2000; Marton & Schwartz, 2003). In contrast, previous research has indicated that children with SLI do not differ from age-matched peers on measures of

phonological recoding in lexical access, as measured by the rapid naming of colours and objects (Vanderwalle et al., 2010). This pattern of findings suggests that children with SLI may have particular difficulty with the encoding and storing of phonological representations a concept not directly addressed in the original work by Wagner and Torgesen (1987), but that they are able to access well-learned representations as quickly as their peers.

Phonological processing is a complex construct, which involves the dynamic processing of information online. It is not a simple linear process and therefore in the study of phonological processing skills, in all populations of children, it is important to fully understand the nature and demands of the tasks used in the research. While many studies have categorised the tasks according to the Torgesen et al. (1994) areas described above, this does not address the commonalities and different processing demands of the tasks themselves. It is important to consider these and map the individual tasks to underlying theoretical frameworks in order to inform our understanding of the processing strengths and weaknesses of children with SLI.

The current research utilises the speech processing model proposed by Stackhouse & Wells, (1997) to explore the processing demands of assessment tasks. This model (Stackhouse & Wells, 1997) consists of three components: a model of speech processing, a speech processing profile and a developmental model. The combination of these components allows clinicians and researchers to plan theory-driven assessment tasks, and to consider the processing demands, including whether tasks require input or output processing or both. Performance can then be interpreted in terms of the developmental phases of the unfolding system.

Input

When verbal information is received it is processed and held in working memory while phonological representations are either accessed or developed (Stackhouse & Wells, 1997; Sutherland & Gillon, 2005). Baddeley and Hitch (as cited in Gathercole & Baddeley, 1990), propose a model of memory consisting of a central executive, which oversees the allocation of attentional resources, and two modality specific buffer systems – the visuospatial sketchpad and the phonological loop. The visuospatial sketchpad is responsible for the integration of visual and spatial information and the formation of a temporary representation (Baddeley, 2003). The phonological loop is responsible for the temporary storage of verbal information, particularly novel phonological input, while other cognitive tasks such as verbal reasoning or auditory comprehension take place, and is often referred to as phonological short term memory (Montgomery, Magimairaj, & Finney, 2010). It comprises two parts - a temporary storage system, which holds the memory trace over a few seconds, and a sub vocal rehearsal system which acts to maintain and refresh the material in the store (Montgomery, 2000). It is widely believed that the phonological loop plays an important role in processing input and the development and storage of phonological representations in the lexicon (Montgomery et al., 2010). The central executive plays an important role in the “coordination of the flow of information throughout working memory” (Montgomery et al., 2010, p. 79). The central executive and phonological loop must work together to ensure that incoming information can be held in short term memory while phonological representations are developed or accessed, drawing on working memory. The episodic buffer was later

added to this model (Baddeley, 2000) and is believed to function as a temporary storage device important in processing chunks of language. These processes result in long term storage.

Just and Carpenter (1992) proposed a computational model of working memory, which considered both the storage and processing functions of the working memory system. This model focuses on the central executive and its role in allocating resources according to task demands. The emphasis, is the trade-off between storage and processing of information when the resources available are exceeded by the demands of the task. This model suggests that capacity limitations constrain language performance and therefore the ability to encode and store finely specified phonological representations (Just & Carpenter, 1992) and suggests that “constraints on working memory capacity should produce quantitative differences among individuals in the time course and accuracy of their processing” (Just & Carpenter, 1992 p 128). It follows then that capacity limitations may constrain language performance and therefore the ability to process, encode and store finely grained phonological representations.

Storage (Lexical representations)

The store, or lexical representation, contains information about the meaning of a word (semantic representation), the grammar of a word (grammatical representation), a set of instructions for producing a word (motor program), and information about how to read and write a word (orthographic representations), as well as a phonological representation (information about the sound of a word) (Stackhouse & Wells, 1997).

It is widely believed that “words are stored and organised in long-term memory according to their phonological features” (Anthony et al., 2010, p. 970). These representations must be well enough defined to allow a child to match previously encoded sound patterns with new instances of the same sound pattern, but also allow for the acoustic variability that occurs both within and between speakers of the same language. Children must begin to form this representation of the sounds of words from a very brief exposure, a process which is often referred to as fast mapping (Fisher, Hunt, Chambers, & Church, 2001)

It is generally accepted that phonological representations are initially a holistic articulatory gesture associated with the meaning of a word. These representations become more distinct and better specified as vocabulary increases (Maillart, Schelstraete, & Hupet, 2004; Snowling & Hulme, 1994). This process, known as “lexical restructuring” continues until the representations consist of phoneme-sized units, which is thought to occur with the acquisition of literacy (Maillart et al., 2004) According to holistic theories, early phonological representations are believed to contain only enough information to distinguish a word from another, and become more specified and segmented as vocabulary increases (Walley, 1993). There is some evidence that young children can distinguish similar sounding words and that their representations may be partly phonologically specified, though it should be noted that the tasks used in these experimental paradigms differ according to processing demands (Mani & Plunkett 2007; White and Morgan 2008).

It has been proposed that low quality, poorly specified phonological representations may affect many other aspects of language (Chiat, 2001; Joanisse & Seidenberg,

1998). For example, Chiat (2001) suggests that development in the areas of vocabulary and syntax relies heavily on phonological information being perceived and represented accurately, and that phonological representations which are poorly specified and imprecise may be the result of the phonological processing weaknesses evident in SLI. Imprecise phonological representations may in turn be reflected in weakness in phonological awareness, and difficulties in reading and spelling.

Output

In order to say a word the stored semantic representation must be activated and retrieved from the lexicon and then the motor program retrieved. In the case of new words which haven't been stored in the lexicon, a new motor program is constructed by selecting stored phonological units and assembling them in new combinations while laying down a new representation. Once the motor program has been either retrieved or constructed the various gestural targets must be assembled in real time taking account of contextual requirements such as rhythm and intonation, as the word is said aloud (Stackhouse & Wells, 1997).

Processing routes of phonological processing tasks.

Many tasks have been used to assess the three broad areas described by Wagner and Torgesen draw on input and output processing skills and require access to lexical representations to varying degrees. For example a rhyme judgement task "listen to these words and tell me which ones rhyme" addresses the question at level D on the speech processing profile *Can the child discriminate between real words?* However, the same rhyme judgement task may be presented silently where the child is required to look at three pictures and point to the two which rhyme, which now addresses the

level F question on the speech processing profile *Is the child aware of the internal structure of phonological representations?* Both require input processing but only the second task requires access to lexical representations.

Nonword repetition tasks address the question at level J on the speech processing profile; *Can the child articulate speech without reference to lexical representations?* Although these tasks require verbal output they do not require the child to access stored phonological representations, as the task requires online creation of a new motor program. Many studies demonstrate that children with SLI have difficulty with nonword repetition (Archibald & Gathercole, 2006; Botting & Conti-Ramsden, 2001; Ellis Weismer et al., 2000; Marton & Schwartz, 2003) and it has been suggested that difficulty in repeating nonwords may be a good phenotypical marker for SLI (Bishop, North, & Donlan, 1996; Conti-Ramsden, Botting, & Faragher, 2001).

Rapid automatised naming (RAN) tasks address the question at level G on the speech processing profile; *Can the child access accurate motor programs?* and are considered to be a measure of phonological processing as it measures the rapid retrieval of phonological codes from the lexicon. It has been suggested that slow performance on RAN tasks may result from imprecise underlying phonological representations which affect accessibility (Snowling, 2000) but difficulties at a motoric level may also have an impact. Performance may therefore be affected by speech output as well as more generally by slow access and processing speed (Wolf & Bowers, 1999).

Many existing measures allow assessment of input and output processing skills, however one of the major limitations in both research and clinical practice with children with SLI has been the lack of valid and reliable measures that allow more direct assessment of phonological representations (the stored sound based representations of words). Many of the tasks used to assess phonological representations are expressive, and require verbal output. In order to explore the quality and accuracy of a stored phonological representation, it is vital to include those that attempt to measure stored phonological knowledge without requiring speech output. While there has been the emergence of reports of such measures with typically developing children and children with speech sound disorder (Sutherland & Gillon, 2005), it is important to apply this method to children with SLI.

Given the acknowledged heterogeneity in the diagnostic group, another major limitation in research into SLI has been the selection of participants. In many previous studies the selection criteria have not been consistent, resulting in difficulties with the interpretation of results. For example, selection criteria for SLI children in many studies have been based on placement at a special language unit (Conti-Ramsden, Botting, Simkin, & Knox, 2001; Conti-Ramsden, Crutchley, & Botting, 1997).

However, as reported by Gathercole (2006) many of the children in these units did not meet the DSM-IV criteria for SLI. Use of stringent selection criteria for SLI is fundamental in advancing our knowledge of the nature, underlying deficits, and outcomes of SLI. In order to develop an understanding of the role and importance of phonological processing skills in specific language impairment it is also crucial to

match the typically developing participants to the SLI participants using stringent criteria.

Aims and objectives

The current program of research adds significantly to the body of research about the nature and underlying deficit in Specific Language Impairment. Many researchers highlight the importance of phonological processing skills in developing, storing and accessing the accurate phonological representations of lexical items required to support the development of language. Previous research has been hampered by inconsistent selection criteria used to select participants, as well as the selection and interpretation of tasks. In order to explore processing theory and specifically the phonological processing difficulties hypothesised to underlie and contribute significantly to the profile of children with SLI, the aims of this program of research were to: i) design and develop measures of phonological representations which do not require a spoken response, ii) test the validity and reliability of the newly developed measures with typically developing children, iii) use these within a broader and systematically designed test battery with children with SLI who were carefully selected in order to increase our understanding of how children with SLI process phonological information.

Design of program of research

One of the objectives of this program of research was to include a well-defined group of children with SLI who met the DSM-IV (Association, 1994) criteria for SLI, as well as tightly matched control groups matched for chronological age and gender

(age-matched), and receptive language skills and gender (language-matched). To ensure that all criteria were met, all participants underwent a series of language and cognitive tests.

In order to explore the accuracy of a child's stored representation of a word, it is vital to have tasks which require children to access stored phonological representations without either hearing a word said, or being required to produce a speech motor output. Such a task involves input processing, but minimal output processing, and facilitates further analysis of processing skills. Thus, the first phase of the research, Paper 1: (Claessen, Heath, Fletcher, Hogben, & Leitão, 2009) and Paper 2: (Claessen, Leitão, & Barrett, 2010) involved the design and development of valid and reliable silent tasks to analyse the quality and accuracy of stored phonological representations. These measures add to our understanding of how phonological representations are stored.

The second phase of the research, Paper 3:(Claessen & Leitão, 2012a) and Paper 4: (Claessen, Leitão, Kane, & Williams, in press) involved using the newly designed and validated measures as part of a battery of phonological processing skills to explore how children with SLI process, store and access phonological information. In this phase of the research, children with SLI were compared to both a group of age-matched, and a group of language-matched peers.

A focus of this program of research has been to consider the processing demands of assessment tasks using a psycholinguistic approach. There are a number of psycholinguistic models of speech processing and these vary in how phonological

representations are described. The final phase of the research Paper 5: (Claessen & Leitão, 2012b) aimed to further explore the structure of the lexicon and consider whether the same phonological representation was accessed for input and output processing tasks. In order to do this, the same multisyllabic words were used as stimulus items for both a judgment and a speech production task.

A summary of the content and findings of each of the published papers is presented below.

Paper 1.

Paper 1, (Claessen et al., 2009) describes the development of the Quality of Phonological Representations task (QPR). The aim was to develop a valid and reliable measure of the accuracy of a stored phonological representation which can be completed nonverbally.

The Quality of Phonological Representations is a computer-presented task which requires a child to listen to a production of a multisyllabic word, judge the accuracy of the production and indicate their response using a computer mouse. It thus measures the accuracy of a stored phonological representation at the whole word level. The task consists of ten multisyllabic words, which are well known to young children. Each word is presented ten times, four productions are correct and six productions where the word has been modified slightly. The child is presented with a picture of the item and asked to judge “Is this a?” and to indicate their response using a computer mouse.

Participants in this study were 235 children attending a mainstream school, who were assessed in their pre-primary year (average age 5 years 5 months). One hundred and

seventy nine of these children were followed up two years later when they were in their third year of formal schooling (average age 7 years 9 months).

The Quality of Phonological Representations task was shown to have adequate reliability and concurrent validity and to be a cost-effective addition to a task battery to identify children at risk of literacy difficulties in early school years.

Paper 2

Paper 2, (Claessen et al., 2010), describes the design and development of the Silent Deletion of Phonemes task. The aim of this phase of the research was to develop a measure of internal phonological representations which has adequate internal reliability and concurrent validity with other measures of phonological processing.

The Silent Deletion of Phonemes task is unique. It requires a child to access a stored phonological representation, without hearing the word spoken aloud, and then silently delete a segment of the word and select the resulting word from an array of four pictures. Thus the Silent Deletion Of Phonemes does not require input or output processing of sound. It measures the child's ability to reflect on the structure of their own stored phonological representation, rather than one that they hear spoken. A response is provided by pointing, and the processing demands are thus restricted to accessing one's own internal representation. Items range in difficulty from deleting part of a compound word (delete 'foot' from 'football') to deleting an internal phoneme from a final consonant cluster (delete the 'n' in 'sand').

The Silent Deletion Of Phonemes was administered to 69 (36 female and 33 male) typically developing children ranging in age from 7; 2 – 8; 1 years, as part of a battery

of phonological processing measures. Performance on the Silent Deletion Of Phonemes was significantly correlated with other measures of phonological processing and not with a measure of nonverbal intelligence.

The Silent Deletion Of Phonemes was shown to be a valid and reliable tool to assess the quality of underlying phonological representations. It was concluded that the Silent Deletion Of Phonemes is a useful addition to the phonological processing skills assessment battery as it provides clinicians with information about the quality of stored phonological representations which is not easily obtained using other clinical tools. Such information supports clinicians' use of psycholinguistic models to explore where breakdowns are occurring in the speech processing process and therefore to plan targeted intervention.

Papers one and two describe phase one of the program of research, the development of two silent measures of phonological representations which did not require a spoken response. Phase two of the research focuses on using the newly developed tasks to explore the profile of phonological processing skills in a well-defined group of children with Specific Language Impairment.

Paper 3.

The aim of the study reported in paper three (Claessen & Leitão, 2012a) was to explore the quality of phonological representations in children with Specific Language Impairment (SLI), as compared to AM and LM peers. The specific hypothesis for this paper was that children with SLI would perform significantly

worse on measures of phonological representations and phonological awareness than age-matched and language-matched peers.

Participants reported in this paper were 21 children with SLI with an average age of 7; 7 (range 6; 10 – 8; 0). Two groups of typically developing participants were also recruited. Twenty-one typically developing children matched for gender, year of schooling and age were recruited as an age-matched group and 21 typically developing children matched for receptive language skills with an average age of 5; 5 (range 4; 11 – 5; 11) were recruited as the language-matched group.

Measures used in this study were the two measures of phonological representations developed in phase one of the research, the Quality of Phonological Representations task (Claessen et al., 2009) and Silent Deletion of Phonemes task (Claessen et al., 2010). The Sutherland Phonological Awareness Test (SPAT) (Neilson, 2003) was selected as the measure of phonological awareness as it is used widely in clinical practice in Australia.

The AM children demonstrated significantly stronger performance than the SLI children on all tasks. On the Silent Deletion Of Phonemes and Phonological Awareness measures both the AM group and the SLI group performed significantly better than the LM group. However on the Quality of Phonological Representations task, the SLI group performed significantly more poorly than either the age-matched or language-matched group. There was no significant difference between the typically developing participants of either age, on the Quality of Phonological Representations task.

As predicted the AM group had significantly better performance on all measures than the SLI group. However the comparison between the SLI group and the LM group was interesting. Both the Silent Deletion Of Phonemes and Phonological Awareness tasks rely on early literacy skills, and therefore the difference in years of schooling, and consequently literacy education, may explain this finding. The relatively strong phonological awareness skills of the SLI participants may have supported their performance on the SDOP task. The significant difference on the Quality of Phonological Representations task supports the hypothesis that children with SLI have lower quality stored phonological representations than typically developing children even those younger children matched for receptive language skills. This finding provides some support for the theory that children with SLI have a weakness in the ability to store/process sound based information.

Paper 4.

The aim of the study reported in paper four (Claessen et al., in press) was to build on the initial phases of the research and use a psycholinguistic model of speech processing to explore how children with SLI store and access phonological information, and compare the processing demands of tasks commonly used to measure phonological processing skills. In this phase of the research, tasks were selected based on the Stackhouse and Wells (1997) speech processing model. A comprehensive battery of phonological processing skills was utilised, incorporating both commonly used measures of rapid naming, short-term and working memory and

phonological awareness, as well as tasks designed to measure the quality of stored phonological representations.

The specific hypothesis for this study was that the profile of phonological processing skills would be different for children with SLI, typically developing children matched for age, and typically developing children matched for language. Participants for this paper were the same as those reported in paper 3.

The research hypothesis was supported with the children with SLI demonstrating a different profile of phonological processing skills to both groups of typically developing children. The pattern of results varied across tasks, and are summarized in table 1.

Table 1 Summary of findings from paper 4.

AREA	MEASURE	RESULTS
Phonological awareness	Sutherland Phonological Awareness Test (SPAT) (Neilson, 2003).	AM significantly better than SLI and LM. SLI significantly better than LM.
	Number repetition subtest of CELF-IV (Semel, Wiig, & Secord, 2003).	AM and LM significantly better than SLI.
Short-term memory	Nonword repetition (Dollaghan & Campbell, 1998)	AM significantly better than SLI. No significant difference between SLI and LM.
	Number repetition backwards subtest of CELF-IV (Semel et al., 2003)	No significant difference between AM and SLI. SLI and AM significantly better than LM.
Working memory	The Competing Language Processing Task (Gaulin & Campbell, 1994).	AM significantly better than SLI. Not administered to LM.
	Rapid naming objects subtest of the Comprehensive Test of Phonological Processing.	AM significantly better than SLI and LM.

(Wagner, Torgesen, & Rashotte, 1999). SLI significantly better than LM.

Phonological representations	Quality of Phonological Representations (Claessen et al., 2009)	AM and LM significantly better than SLI. No significant difference between AM and LM.
	Silent Deletion Of Phonemes (Claessen et al., 2010)	AM significantly better than SLI, and LM. SLI significantly better than LM.

The findings reported in paper four provide some support for the theory that a deficit in phonological processing skills may be a strong contributor to the underlying deficit in SLI. Of particular interest was the difference between groups on the digit repetition task and the QPR. These results suggest that deficits in short term phonological memory may have impacted on the ability to develop precise phonological representations for multisyllabic words.

Paper 5.

Psycholinguistic models vary in how phonological representations are described. In some models, no distinction is made between input and output phonological representations (Griffiths & Snowling, 2001). In others (Monsell, 1987; Stackhouse &

Wells, 1997), separate, but linked, phonological representations are proposed for speech input and output. In the Stackhouse and Wells (1997) model the output phonological representation is termed called the motor program. The final phase of the program of research is reported in paper five (Claessen & Leitão, 2012b) which aimed to explore the structure of phonological representations, and consider whether the same stored phonological representation is accessed for input and output speech processing tasks or whether these draw on separate phonological representations. One unique aspect of paper five was the use of the same multisyllabic word stimulus items for both the input and output speech processing tasks. In this phase of the research children judged the accuracy of heard productions of multisyllabic words. They were later asked to name each item as a production task. It was hypothesised that there would be a correlation between the ability to name an item and judgment of the accuracy of a spoken production of the word which would suggest a single phonological representation accessed for both input and output phonological processing tasks. It was also hypothesised that children with SLI would have poorer performance on the speech output task than typically developing peers, but that their performance would not be significantly different to younger children matched for receptive language skills.

Participants in this phase of the research were the same sixty three children who participated in the study reported in papers three and four. The QPR task (Claessen et al., 2009) was used as the input processing measure. Following administration of the QPR, the output processing task was administered, which required each child to name the ten multisyllabic words from the QPR task.

When semantic accuracy was considered (i.e. whether the child knew the name of the word), there was no significant difference between the groups, with all children knowing the names of each item. When phonological accuracy was considered however, there was a significant difference between the LM group and both the SLI and AM groups. The LM group had significantly weaker performance than either the AM or SLI groups. Given that the LM group is, on average two years younger than the other groups, this finding is not surprising.

In contrast to our hypotheses, there was no correlation between the ability to name an item and judgment of the accuracy of a spoken production of the word, for any group. This finding suggests separate input and output phonological representations and is consistent with speech processing models such as Monsell (1987) and Stackhouse and Wells (1997) which propose separate phonological representations.

The papers outlined above are presented as chapters 2-6 of this exegesis. Chapter seven then provides an overall summary of the findings, and discusses theoretical and clinical implications of the research program

Paper 1: Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language & Communication Disorders*, 44(2), 121-144.

Quality of phonological representations: a window into the lexicon?

Mary Claessen[†], Steve Heath[‡], Janet Fletcher[‡], John Hogben[‡] and Suze Leitão[†]

[†]Human Communication Science, School of Psychology, Curtin University of Technology, Perth, WA, Australia

[‡]School of Psychology, University of Western Australia, Perth, WA, Australia

(Received 2 May 2007; accepted 29 January 2008)

Abstract

Background: There is a great deal of evidence to support the robust relationship between phonological awareness and literacy development. Researchers are beginning to understand the relationship between the accuracy and distinctiveness of stored phonological representations and performance on phonological awareness tasks. However, many of the tasks currently used to assess the integrity of underlying representations are confounded by requiring spoken output.

Aims: This paper describes the development of the Quality of Phonological Representations (QPR) task, a task that does not require speech output, and its evaluation in the context of a larger study examining predictors of literacy outcomes in Western Australia.

Methods & Procedures: The QPR task was given as part of a larger task battery to a cohort of 235 mainstream children in the last term of their Preprimary year (average age=5;5) and to 179 children at follow-up at the end of Year 2 (average age=7;9).

Outcomes & Results: Normative data for both accuracy and reaction time are presented in percentile tables (appendix B). In their Preprimary year, children were able to identify correct productions of multi-syllabic words (hits) on average 87.5% of the time, rising to an average of 93.8% in Year 2. As expected, children became quicker at making these judgements, reaction time shifting from an average of 1.1 s in Preprimary to 0.83 s in Year 2. A similar pattern was observed with the data for correct rejections. To make these judgements, the children had to identify a pseudo-word as an incorrect pronunciation by 'Katie the computer'. In the Preprimary year, children were able to reject correctly the pseudo-words on average 68.5% of the time, rising to an average of 81.7% in Year 2. As expected, children became quicker at making these judgements,

Address correspondence to: Mary Claessen, Human Communication Science, School of Psychology, Curtin University of Technology, GPO Box U1987, Perth, WA 6845, Australia; e-mail: M.Claessen@curtin.edu.au

reaction time shortening from an average of 1.4 s in Preprimary to 0.81 s in Year 2. The QPR task was shown to have moderate reliability and concurrent validity. *Conclusions:* The QPR task appears to be a useful and cost-effective addition to task batteries aiming to identify at-risk children in the early stages of schooling. The ability to profile children's phonological awareness skills and gain insight into their underlying phonological representation skills allows more informed goal setting and intervention planning.

Keywords: phonological representations, phonological awareness, assessment, literacy development.

What this paper adds

There is a great deal of evidence to support the robust relationship between phonological awareness and literacy development. Researchers are also beginning to understand the relationship between the accuracy and distinctiveness of stored phonological representations and performance on phonological awareness tasks. Many tasks currently used to assess the integrity of underlying representations are confounded by requiring spoken output. This paper outlines the development of the Quality of Phonological Representations (QPR) task, a task that does not require speech output. This allows one to 'open the window' into the lexicon and measure the accuracy and integrity of the underlying phonological representation. Profiling both children's phonological awareness skills and their underlying phonological representation skills allows more informed goal setting and intervention planning.

Introduction

There is a great deal of evidence to support the robust relationship between phonological awareness (PA; the explicit awareness of sounds in words) and literacy development (Wagner *et al.* 1994). The ability to reflect on the sound structure of words, analyse and manipulate these sound segments and map sounds to letters forms a strong foundation for developing literacy (Gillon 2004). Difficulties with PA are considered a core deficit in many children with reading disabilities (Catts *et al.* 2002).

As a result, a large body of research over the past 20 years has investigated the identification of children demonstrating difficulties in PA before the beginning of reading (e.g., Liberman and Shankweiler 1985, Gillon 2004, Snowling 2000a). Lonigan *et al.* (2000) studied the predictive significance of emergent literacy skills in two samples of children (mean age 41 months and 60 months) by following them from late preschool to early grade school. In this study, measures of PA and letter knowledge were shown to be unique predictors of subsequent decoding skills. Catts *et al.* (2001) found a measure of PA in the American Kindergarten year (i.e., 5 year olds) was one of five measures that predicted the presence of a reading disability in grade 2. Hogan *et al.* (2005) demonstrated that a measure of PA in the kindergarten year accounted for unique variance in reading skills in grade 2 beyond that accounted for by letter identification tasks. Cost-effective prediction of reading

difficulties using PA in this age group was investigated in Western Australia by Heath and Hogben (2004). A brief screening procedure which began by assessing PA in all 5-year-old children, then following up those who fell in the bottom quartile of the PA distribution on measures of sentence recall, age, sex and parents' educational levels was shown to prospectively identify 80% of poor readers at the end of Year 2 (Heath and Hogben 2004).

A smaller body of research has investigated the development of PA and literacy skills in children with speech and language impairments (Snowling 2000b). This group of children has been shown to be at increased risk of literacy difficulties, making early identification even more critical (Stackhouse and Wells 1997b, Leitão *et al.* 2000, Leitão and Fletcher 2004, Nathan *et al.* 2004). However, not all children with speech and language impairment have limited PA skills or go on to develop literacy difficulties (Dodd and Gillon 2001, Hesketh 2001).

Although the evidence for PA as a central predictor for literacy is extremely strong in children with speech and language difficulties, what is still unsure after all this research is which preschoolers with poor PA will go on to develop literacy problems. Clinicians, educators and researchers need to be able to identify at an early age those speech and language impaired children who are at increased risk in order to plan appropriate effective and evidence based intervention.

Within both these bodies of research, which explore the development of PA in the typically developing population and in children with speech and language impairments, evidence is emerging that attests to the importance of phonological representations in supporting the development of PA skills and hence the development of reading and spelling (Carroll and Snowling 2004).

Phonological representations

Phonological representations can be defined as the sound based codes associated with words, and the storage of this phonological information in long term memory. In the early stages of language development, a child is considered to associate a holistic, articulatory gesture with the meaning of a word. With the rapid growth of vocabulary, it is hypothesized that this storage becomes unwieldy, driving the stored 'code' to take on a segmental nature, with progressively smaller units being stored until the representations contain phoneme-sized units (Fowler 1991, Walley 1993, Metsala and Walley 1998). This process has been called lexical restructuring and is thought to continue to develop up to 8 years of age.

Researchers are beginning to understand the relationship between the accuracy and distinctiveness of stored phonological representations and performance on PA tasks. Problems in establishing accurate, distinct and fine-grained phonological representations in long-term memory are considered a key factor in accessing sub-lexical units (i.e. developing PA) and learning the alphabetic principle (Elbro 1998). PA tasks have been interpreted as in some way providing researchers with a 'window into the lexicon', shedding light onto the segmental nature and accuracy of the stored, underlying representations (Claessen *et al.* 2004). Poorly specified representations will impact on the development of awareness of the sounds within the words, thus predicting performance on measures of PA. Poor quality representations may also impact on a child's ability to use phonological information in reading and spelling (Sutherland and Gillon 2005). Evidence has also been found

to support the notion of less mature phonological representations in children with dyslexia (Boada and Pennington 2006).

The impact may be greatest for those children whose speech and language impairment is characterized by underlying difficulties in processing phonological information and who have laid down poorly specified or even inaccurate representations. The literature describes clinical examples of imprecise word productions and multi-syllabic word repetition considered to result from ‘fuzzy’ underlying phonological representations and motor programmes (Catts and Kamhi 1999, Leitão 2003). This group of children is described as experiencing increased difficulty with literacy development even after their speech output difficulties have resolved and their language skills appear to be functioning within the normal range (Nathan *et al.* 2004).

Measuring the quality of phonological representations

A review of the literature uncovers a range of innovative ways in which researchers have tackled the task of assessing the integrity of phonological representations. These include: naming, non-word repetition, gating, making judgements and corrections, and auditory lexical decision tasks.

The work of Stackhouse and Wells (1997a, 2001), whose speech-processing model as shown in figure 1, provides a framework to consider the processing demands of assessment tasks can be used to interpret the tasks (Stackhouse and Wells 1997a, 2001). The model provides a visual representation of the input processing, lexical representations and output processing involved in processing and producing words (Stackhouse and Wells 1997a).

The speech processing profile (figure 2) is a tool used to pose a series of questions and allow assessment data to be organized into a summary profile of a child’s strengths and weaknesses based on the model (Stackhouse and Wells 1997a). Level E, which asks the question ‘Are the child’s phonological representations accurate?’ is concerned with collecting data on a child’s underlying representations of a word, the step we are aiming to investigate.

As we outline the different types of tasks from the literature that have been used to assess the integrity and quality of underlying phonological representations, we will explore the difficulties in isolating the level of processing affected by the task demands, and the confounds present in the different types of tasks.

Naming

There are two main types of naming tasks: the confrontation picture naming task and the speeded naming task (Swan and Goswami 1997). The confrontation picture-naming task involves the presentation of pictures of objects, ranging from the more common to the less common. These tasks measure retrieval of phonological information coded and stored in long term memory. The speeded naming task involves the presentation of pictures of common objects, colours, numbers or letters. The presentation of these stimuli can be in a rapid alternating form or in a discrete trial format. The stimuli are all highly familiar, thus the tasks measure the speed with which the child is able to retrieve over-learned symbolic information from memory (Swan and Goswami 1997). Naming tasks have been used in children

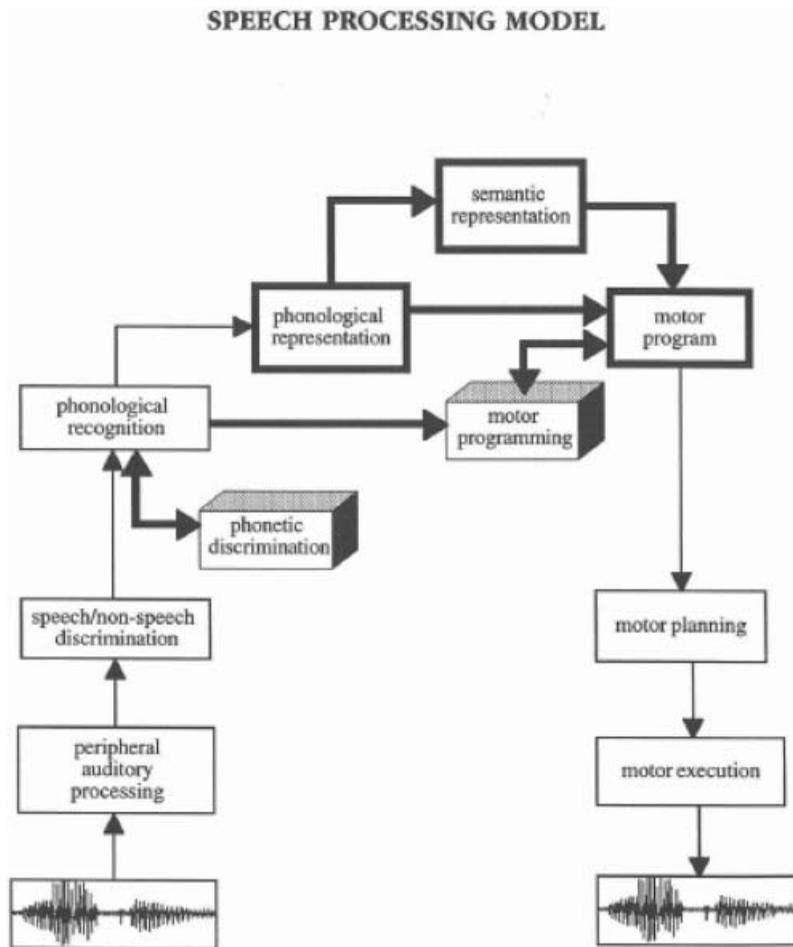


Figure 1. The speech processing model. Source: Stackhouse and Wells (1997a). Copyright: John Wiley & Sons Ltd. Reproduced with permission.

with dyslexia as an indicator of potential weakness in storage and access of phonological representations (Elbro 1998, Snowling *et al.* 1988).

The processing route taken by naming tasks starts with accessing the semantic representation stimulated by the presentation of a picture which then triggers the existing motor programme (figure 1). Accuracy is therefore influenced by picture recognition (involving visual processing) and semantic knowledge. In addition, inaccurate production of the label may reflect an inaccurate phonological representation and/or stored motor programme and/or difficulties at a motoric level. Performance on naming tasks may therefore be affected by speech output difficulties.

Non-word repetition

The non-word repetition tasks require a child to hear and then immediately repeat a series of nonsense or pseudo-words. Researchers have shown that the phonotactic

SPEECH PROCESSING PROFILE

Name: _____ Comments: _____

Age: _____ d.o.b: _____

Date: _____

Profiler: _____

INPUT	OUTPUT
<p>F</p> <p>Is the child aware of the internal structure of phonological representations?</p>	<p>G</p> <p>Can the child access accurate motor programs?</p>
<p>E</p> <p>Are the child's phonological representations accurate?</p>	<p>H</p> <p>Can the child manipulate phonological units?</p>
<p>D</p> <p>Can the child discriminate between real words?</p>	<p>I</p> <p>Can the child articulate real words accurately?</p>
<p>C</p> <p>Does the child have language-specific representations of word structures?</p>	<p>J</p> <p>Can the child articulate speech without reference to lexical representations?</p>
<p>B</p> <p>Can the child discriminate speech sounds without reference to lexical representations?</p>	<p>K</p> <p>Does the child have adequate sound production skills?</p>
<p>A</p> <p>Does the child have adequate auditory perception?</p>	
<p>L</p> <p>Does the child reject his/her own erroneous forms?</p>	

Figure 2. The speech processing profile. Source: Stackhouse and Wells (1997a). Copyright: John Wiley & Sons Ltd. Reproduced with permission.

probability of the non-word, affects the repetition latency, accuracy and duration (Vitevich and Luce 1999, Munson *et al.* 2005). Edwards *et al.* (2004) reported that the sequences of phonemes found very rarely in real words were repeated less accurately and that the decline was correlated more strongly with vocabulary than with age. They hypothesized that as vocabulary increases, a more refined, segmented representation is required to differentiate a word from its neighbour, as neighbourhood density will increase in parallel with the development of vocabulary. Munson *et al.* (2005) proposed that with the development of vocabulary, children become more able to perceive phonemes as separate from the words in which they occur. In other words, they develop the more distinct representations that are required for literacy development.

Difficulties performing non-word repetition tasks may therefore reflect poor encoding skills and in consequence, the distinctness of a stored representation. However, as they require the participant to produce a non-word, performance can also be affected by problems with writing new output motor programmes, and/or speech output difficulties which may reflect speech output constraints even for children who do not present with a speech disorder (figure 1).

Gating

The gating paradigm developed by Grosjean (1980) involves the identification of words from increasingly longer segments of the acoustic signal and has been used by a number of researchers in this area to investigate perception and recognition of spoken words (Grosjean 1980, Boada and Pennington 2006). Wesseling and Reitsma (2001) investigated the quality of underlying phonological representations and the development of reading skills in Dutch children aged 5–6 years using a gating task as part of their battery. The inconsistency in gating task performance was interpreted to reflect that these tasks were not suitable to use as a measure of quality of phonological representations.

Performance on gating tasks, while testing the quality of a child's underlying phonological representations, may also be affected by weaknesses in auditory input and discrimination. In addition it may be influenced by difficulties accessing the underlying phonological representation and, again, by speech output difficulties (figure 1).

Judgement

Tasks that require children to make judgements about the accuracy of another's production, go some way towards tapping into underlying representations without the contamination of a verbal response. An innovative task by Elbro (1998) designed to examine the distinctness of phonological representations, involved children judging and correcting a puppet's production of multi-syllabic words. The children were told that the puppet had some speech difficulties and their job was to teach the puppet the most distinct pronunciation of a series of multi-syllabic words. This task was shown to predict performance on PA and reading tasks at age 8 years and was hypothesized to provide information on underlying representations. By requiring a verbal response, however, performance could be affected by speech output difficulties (figure 1).

Lexical decision

In order to investigate the integrity of a child's underlying phonological representation, to open the 'window into the lexicon', we need to develop a judgement task that minimizes output requirements. The processing route should entail a child accessing and reflecting on the accuracy of their underlying phonological representations without requiring a verbal response. This type of task addresses Level E on the Stackhouse and Wells (1997a) speech processing profile by asking: 'Are the child's representations accurate?' (figure 2).

The child is asked to judge if a spoken word matches the name of the object they see depicted on the screen. The presumed processing route first requires activation of the visual recognition system to identify the single picture (e.g. helicopter). The semantic representation is then accessed. The lexical decision involves comparison of the child's stored phonological representation of the word with the heard spoken stimulus. As the child's response is non-verbal, the impact of speech output difficulties is minimized.

Tasks such as the auditory detection of speech errors task (Locke 1980) have been used previously to explore this question. The examiner creates a list of words specific to a child: the target word (e.g. 'car'), the typical error produced by the child (e.g. 'tar') and a control word (e.g. 'sar'). The child is presented with a randomized set of these 'words' spoken by the examiner who asks e.g. 'Is this a "tar"?' Data are gathered to inform the clinician as to whether the child can hear the difference between their production and the target. Similarly, a lexical decision task was described by Crosbie *et al.* (2002) which aimed to assess a child's ability to identify a string of speech sounds as a familiar word or reject it as an unfamiliar string. This was considered to tap stored word phonology by requiring a child to discriminate the heard string and compare it with stored phonological representations (Crosbie *et al.* 2002).

Recent work by Sutherland and Gillon (2005, 2007) used an accuracy judgement task with children with speech impairment. The task required the participants to decide if a spoken word was a 'good' or 'not a good' way of saying the target word when they were presented with pictures of the target and heard a pre-recorded production of the word. The results demonstrated that preschool children with speech impairment experienced more difficulty making such judgements than a group of children without speech impairment. The judgement task was shown to be positively correlated with other areas known to influence literacy development such as vocabulary and letter knowledge (Sutherland and Gillon 2005). The authors suggested that task sensitivity could be improved by further fine-tuning of the stimulus items using information on known areas of weakness in children's developing phonological systems. This would require the children to make judgements about words using their own error productions, similar to those required in the Locke task described above (Locke 1980).

The findings described above provide support for the further development and use of receptive judgement tasks, as recommended by Sutherland and Gillon (2007). Tasks designed to minimize potential confounding factors allow a researcher or clinician to make more confidently inferences about the accuracy and integrity of the underlying phonological representations — reflecting their quality.

Speed of processing

In addition to exploring quality, researchers have also turned their attention to the accessibility of the underlying phonological representations. In other words, representations should be not only fine-grained and accurate, but access to the word should be quick and efficient.

Rapid naming tasks are used to time retrieval of phonological codes and many studies have documented the difficulties experienced by poor readers in rapid naming (Catts *et al.* 2002). Rapid automatized naming tasks have also been shown to be a strong predictor of reading outcomes (Felton and Brown 1990). It has been suggested that slow performance on RAN tasks may result from imprecise underlying phonological representations which affects accessibility (Snowling 2000a), or more generally from slow access and processing speed (Wolf and Greig Bowers 1999).

Slower responses may reflect an inaccurate phonological representation and/or stored motor programme but also difficulties at a motoric level. Performance on these tasks may therefore be affected by speech output difficulties as well as possible speed of processing issues.

Timing children's responses on task items such as during lexical decision tasks has been suggested as a means of providing valuable information on accessibility of underlying representations (Sutherland and Gillon 2005). Fawcett and Nicolson (1994) compared children with dyslexia with age- and reading age-matched controls and carried out a series of response time tasks. Children with dyslexia did not differ from controls on simple response time tasks but were significantly slower on selective choice and a lexical decision task (which required children to judge a word as real or a non-word). However, as yet, there are no reported tasks which collect both accuracy and latency data, and hence can provide insight into the quality and accessibility of underlying phonological representations.

Aims

As a consequence of these established needs, the current study aimed to do the following:

- (1) Develop a Quality of Phonological Representations (QPR) task that limited the confounds of production by requiring no verbal output from the child; fine tuned the stimulus items by systematically varying the vowels and consonants in the design of the pseudo-words used in the task; measured latency of response in addition to accuracy in order to provide information on accessibility as well as quality of the underlying representation.
- (2) Provide norms for the QPR task for children in Preprimary and Year 2.
- (3) Establish the reliability and stability over time of the QPR task.
- (4) Establish the concurrent and criterion validity of the QPR task.

Aims (2)–(4) were addressed within the context of a larger study examining predictors of literacy outcomes in Western Australia. The Catch Them Before They Fall project (Heath *et al.* 2006a, b) was designed to validate and fine tune the screening approach suggested by Heath and Hogben (2004) to identify children at risk for literacy difficulties.

Methods

Developing the QPR task

Pilot testing in a group of mainstream children generated a list of twelve multi-syllabic words which were highly imageable and familiar to children of that age, Clipart pictures and hand drawn sketches were sourced for each word and these were stored electronically.

For each multi-syllabic word, a range of pseudo-words was generated by varying the consonants for place, manner and voicing, and varying vowels across the following dimensions: high–low, front–back and long–short. In addition, based on clinical experience, some commonly heard childhood productions of multi-syllabic words were included for example *basgetti* (bʔzgeti) and *binocliars* (bʔnʔkliʔz). This resulted in a list of 240 pseudo-words from which the final selection of 72 pseudo-words (six for each of the twelve multi-syllabic words) was made. (See appendix A for a complete list of stimulus items.)

The QPR task used a laptop computer to present children with pictures of the multi-syllabic words. The children were required to judge correct or incorrect productions of the words by selecting a tick or a cross on the computer screen. No verbal response was required. For each stimulus item, the child heard four correct productions and six pseudo-words. These real words and pseudo-words were digitally recorded by an Australian, monolingual, female speaker, and stored as WAV files using Cool Edit software.

A computer program was written using Matlab to randomly present each picture and word combination and, on computer mouse click, both accuracy and reaction time were collected and stored for later analysis.

Evaluating the QPR task

Participants

Participants were recruited as part of the Catch Them Before They Fall project. A stratified sample frame was constructed to represent as closely as possible mainstream schools across the Perth metropolitan area (Western Australia) on the basis of education district, socio-economic level and school size. A random selection of schools within each stratum was invited to participate in the study. Schools were asked to allow one whole class of Preprimary children to participate (or in schools with multiple Preprimary classes, the equivalent number of children from across their total Preprimary enrolment). This yielded a sample of 241 children with an average age 5,5 (0.25) when the study commenced in the middle of the children's Preprimary year. By the time testing on the QPR task began, six students had moved to other schools, leaving 235 participants in this study (114 males and 121 females), of which 31 were identified as having English as a Second Language backgrounds. These children were not excluded as we wished to determine the usefulness of the QPR task across a range of Preprimary children. All testing for the project was carried out within the literacy education programmes of participating schools except for the measurement of non-verbal abilities, for which parents gave their consent. Non-verbal ability testing was completed at the commencement of Year 1, then 179 of the participants were followed up in Term 4 of Year 2 when their average age was 7,9 (0.25). Some participants were unable to be followed up as they had moved to

schools outside the metropolitan area, interstate or overseas or otherwise were not able to be traced (retention rate=0.76).

Detailed characteristics of the sample reported by Heath *et al.* (2006b) indicate that measures of central tendency and variance for key standardized variables including performance IQ and oral language were within the expected range.

Psychometric testing

The Catch Them Before They Fall test battery included measures of language, intelligence, PA, phonological processing and early literacy skills, descriptions of which are detailed in Heath *et al.* (2006b). Tasks relevant to the current paper were measures of PA and quality of phonological representations. These variables were assessed in Terms 3 and 4 of participants' Preprimary year and again in Terms 3 and 4 of Year 2. All participants were individually tested in a quiet area of their own school.

Phonological awareness was measured by the Sutherland Phonological Awareness Test — Revised: Form A (SPAT-R; Neilson 2003). The SPAT-R is a simple yet thorough standardized test that provides a diagnostic overview of the PA skills required for early literacy development. The test assesses awareness of syllables, onset/rime, and phonemes, including blends or clusters. Tasks involve identification, blending, segmenting, and phoneme deletion. The SPAT-R is normed on an Australian sample and provides percentile scores. This standardized measure was administered according to the test instructions and both raw scores and standard scores were entered into our data analyses.

Quality of phonological representations was measured by the QPR task. This task was administered using an Acer Travelmate 4150. Children were trained on the two least familiar stimulus items (boomerang and ambulance). The ten productions of each of the ten test stimuli (correct and pseudo-words) were then presented randomly.

For each item, a picture was presented on the computer screen. Simultaneously, the child heard through headphones 'Is this a _____?' followed by either a word or pseudo-word. The child indicated his/her response by using a mouse to click on either a red cross for 'no' or a green tick for 'yes'. Items were presented once and rate of presentation was controlled by the experimenter who was seated on the child's right.



Figure 3. An example of what the child would see on the computer screen on any given trial.

Results

Description of children's performance on QPR

Accuracy data were recorded and categorized in the following way (figure 4) using a signal detection rationale (Maillart *et al.* 2004).

The data of interest in this design are hits and correct rejections. Accuracy for hits yielded a total out of 40, and correct rejections were scored out of 60. The raw scores were converted to percentages. Reaction time was recorded in seconds. Each child's median reaction time for the relevant set of trials was calculated. Group mean accuracy and reaction time data are reported in table 1.

Both Preprimary and Year 2 distributions for hits were heavily negatively skewed because, as we might expect, a lot of the children were already able to make very quickly and accurately, the easier judgement of whether a correct pronunciation was correct or not.

The distributions for correct rejection of an incorrect pronunciation more closely approximated normality, though once again they were shifted towards the

Hit Is this spaghetti? Yes	Miss Is this spaghetti? No
False alarm Is this spaghotti? Yes	Correct rejection Is this spaghotti? No

Figure 4. Response categories for Quality of Phonological Representations (QPR) accuracy.

Table 1. Descriptive statistics for Quality of Phonological Representations (QPR) task accuracy and reaction time

	Preprimary (<i>n</i> =235)			Year 2 (<i>n</i> =179)		
	Mean	SD	Range	Mean	SD	Range
<i>Response type (%)</i>						
Hits	87.5	11.6	22–100	93.8	7.0	50–100
Correct rejections	68.5	18.5	3–93	81.7	11.2	25–98.3
<i>Reaction time (s)</i>						
Hits	1.1	0.6	0–3.5	0.83	0.37	0.1–2.3
Correct rejections	1.4	0.6	0.3–4.3	0.81	0.31	0.3–2.1

SD, standard deviation.

high performance end. Even so, the correct rejection data did give a very good range of scores in the tail suggesting that these two measures were discriminating among the children of most interest in the present study (i.e., those performing badly because they are drawing on the poorly resolved mental representations). For this reason, it seemed most parsimonious to focus our remaining analyses on the correct rejection accuracy and latency data. Norms for accuracy and latency of correct rejections for children in Preprimary and Year 2 are provided in appendix B.

To determine if the quality of children's representations had improved significantly with development and with exposure to literacy education, between Preprimary and Year 2, paired samples *t*-tests were carried out on the correct rejection data. Children had become significantly more accurate: $t(174)=10.36$; and took significantly less time: $t(174)=12.14$; to make the judgements required, with both *t*-values significant at $p<0.001$. Distributions were of course more heavily negatively skewed, but as can be seen from table 1, there were still some children who performed very poorly on this task.

Reliability of QPR task

Cronbach's alpha (α) was calculated to determine the internal consistency of the QPR task. For the Preprimary sample, $\alpha=0.93$, and for Year 2 it was 0.84, reflecting strong internal consistency (Pring 2005).

We also considered the stability of the task within individual children during the beginning period of literacy instruction. We found moderate stability over time for both accuracy and latency of correct rejection ($r=0.43$ and 0.32 , respectively, $p<0.001$). Interestingly, children's performance over time in PA as measured by the SPAT-R from Preprimary to Year 2 showed a similar degree of stability ($r=0.44$, $p<0.001$). We used cross-tabulation to determine the likelihood of children who began school with poor QPR remaining that way. We found that Preprimary children in the bottom quartile for correct rejection accuracy had a 0.41 chance of still being in the bottom quartile at the end of Year 2, compared with children in any of the three top quartiles, who had only a 0.16 chance of becoming that weak by the end of Year 2: $\chi^2(1)=12.50$, $p<0.001$. Thus, weakness in this area seems to be a relatively stable characteristic.

Concurrent and construct validity

We were unable to measure concurrent validity in the true sense, because there was no previous, satisfactory measure of quality of phonological representations. However, on the basis of the literature reviewed above, we reasoned that correct rejection of a pseudo-word — an incorrect pronunciation, requires well-specified phonological representations. If a child has better quality representations, these would also arguably lead to better PA. Therefore, we might expect performance on the correct rejection judgement to be related to PA. The SPAT-R, an accepted measure of PA, was used to provide us with data to use to measure construct validity of the QPR.

Using a correlation approach, we found a modest relationship between Preprimary accuracy of correct rejections and SPAT-R score after controlling for performance IQ ($r=0.37$, $p=0.001$). The relationship between latency for correct

rejections and PA was somewhat weaker ($r=0.23$, $p=0.001$). These relationships were less strong in Year 2: correct rejection accuracy versus SPAT-R ($r=0.19$, $p=0.015$); and correction rejection reaction time versus SPAT-R ($r=0.11$, n.s.). However, we do not think that correlation analysis fully captures the complexity of the relationship between quality of the underlying phonological representation and PA. The literature predicts the likelihood that the relationship will be stronger in one direction than the other — in other words, that quality of phonological representations is likely to predict PA skills (Elbro 1998, Gillon 2004).

Cross-tabulation analysis quantified this predicted relationship better. Table 2 shows that Preprimary children falling in the bottom quartile of the correct rejection accuracy distribution had a two in three chance of being in the bottom quartile on the SPAT-R distribution, but only a one in 20 chance of being in the top quartile. In contrast, children falling in the top three quartiles on this measure had an approximately equal chance of being in any of the four quartiles of the SPAT-R distribution.

For correct rejection reaction time, children in the bottom quartile had a four times better chance of also being in the bottom quartile on the SPAT-R distribution (0.40) than of being in the top quartile (0.10). Once again, children falling in the top three quartiles on this measure had a fairly equal chance of being in any of the three top quartiles of the SPAT-R distribution.

Conversely, children falling in the bottom quartile of the SPAT-R (table 3), had a 52% chance of being in the bottom quartile of the QPR accuracy and only a 6% chance of falling into the top quartile — demonstrating a similar but weaker relationship, as predicted. For QPR reaction time, the scores are spread more evenly across the SPAT quartiles.

Predictive validity

Finally we considered how well the QPR task performance predicted literacy outcomes. Heath *et al.* (2006b) classified Year 2 children into those who were *functional* at literacy because they were in the top three quartiles on their composite literacy measure, or *poor* at literacy, because they were in the bottom quartile on this

Table 2. Probability of children in the bottom quartile or in the top three quartiles for correct rejection accuracy and reaction time being in any specified quartile for Sutherland Phonological Awareness Test — Revised: Form A (SPAT-R)

Preprimary QPR quartile	Preprimary SPAT-R			
	1 Top Q	2	3	4 Bottom Q
<i>Correct rejection (accuracy)</i>				
Top 3	0.25	0.27	0.25	0.24
Bottom	0.05	0.13	0.16	0.66
<i>Correct rejections (reaction time)</i>				
Top 3	0.25	0.27	0.25	0.23
Bottom	0.10	0.23	0.27	00.40

Table 3. Probability of children in the bottom quartile or in the top three quartiles for Sutherland Phonological Awareness Test — Revised: Form A (SPAT-R) being in any specified quartile for correct rejection accuracy and reaction time

Preprimary SPAT-R quartile	Preprimary QPR quartiles			
	1 Top Q	2	3	4 Bottom Q
<i>Preprimary QPR accuracy</i>				
Top 3	0.26	0.29	0.28	0.18
Bottom	0.06	0.17	0.25	0.52
<i>Preprimary QPR reaction time</i>				
Top 3	0.27	0.25	0.30	0.19
Bottom	0.22	0.25	0.14	0.39

QPR, Quality of Phonological Representations.

measure. QPR scores in Preprimary were examined for their ability to predict literacy outcomes in Year 2.

Table 4 shows that children in the bottom quartile of QPR correct rejection accuracy in Preprimary had a 45% chance of falling into the lowest quartile for literacy outcomes in Year 2 but only a 10% chance of falling in the top quartile. Children falling in the top 3 quartiles had a fairly even chance of falling into any of the four quartiles for literacy outcomes in Year 2.

Conclusions

Phonological representations are increasingly considered to play an important role in the development of PA and hence literacy (Snowling 2000a, Catts *et al.* 2001, Gillon 2004), and children with reading disability are thought to have poor phonological representations (Boada and Pennington 2006). Measuring the quality and accessibility of children's underlying phonological representations should help 'open the window into the lexicon'. Yet, most tasks currently available that purport to assess underlying representations are confounded by the need for a verbal response.

The QPR task is a lexical decision judgement task designed to explore the development of a child's phonological representations without requiring a verbal response. This paper describes the development of the QPR task — its theoretical

Table 4. Probability of children in the bottom quartile or in the top three quartiles for correct rejection accuracy being in any specified quartile for literacy outcomes

Preprimary QPR quartile	Composite literacy Year 2 quartiles			
	1 Top Q	2	3	4 Bottom Q
<i>Pre-primary QPR accuracy</i>				
Top 3	0.29	0.23	0.28	0.20
Bottom	0.10	0.28	0.18	0.45

QPR, Quality of Phonological Representations.

underpinnings, aims and implementation. Detailed information about the task design is provided such that the task can be replicated. Longitudinal data from a large sample of WA mainstream children in their Preprimary year (average age=5;5) and at follow-up at the end of Year 2 (average age=7;9) are presented in appendix B, providing percentile scores on accuracy of performance and response latency for correct rejections on the task. The QPR task is shown to have moderately strong validity and reliability.

As a measure of quality of phonological representations we were interested in children's ability to judge whether multi-syllabic words were pronounced correctly. In their Preprimary year, children were able to identify correct productions of multi-syllabic words (hits) on average 87.5% of the time, rising to an average of 93.8% in Year 2. As expected, children became quicker at making these judgements, reaction time shifting from an average of 1.1 s in Preprimary to 0.83 s in Year 2.

A similar pattern was observed with the data for correct rejections. To make these judgements, the children had to identify a pseudo-word as an incorrect pronunciation by 'Katie the computer'. In the Preprimary year, children were able to reject correctly the pseudo-words on average 68.5% of the time, rising to an average of 81.7% in Year 2. As expected, children became quicker at making these judgements, reaction time shortening from an average of 1.4 s in Preprimary to 0.81 s in Year 2.

Interestingly, this sample of Preprimary children from mainstream schools accepted an incorrect production of a multi-syllabic word as accurate, on average 31.5% of the time, and in Year 2, 18.3% of the time. When we looked at the data qualitatively, it was varying the place of production of nasals, voicing and height of vowels where errors were most likely to occur.

We explored the relationship between quality of phonological representations, as measured by ability to reject correctly an incorrect pronunciation of a multi-syllabic word, and PA skills in the Preprimary children in more detail. We found that being in the bottom quartile for QPR accuracy of correct rejections, gave a 66% chance of also falling in the bottom quartile of the PA measure — the SPAT-R, and for latency, a 40% chance. In contrast, falling in any of the top 3 QPR quartiles for accuracy or latency yielded an almost even chance of falling in any of the four PA quartiles. In other words performing poorly on the QPR task (falling below the 25th percentile) usually indicated poor PA.

This relationship also held in the other direction, but was weaker, supporting the predicted direction of the relationship. The literature predicts the likelihood that the relationship will be stronger in one direction — in other words, that quality of phonological representations is likely to predict PA skills (Elbro 1998, Gillon 2004). Poorly specified, inaccurate representations will impact on a child's ability to efficiently access and reflect on the segmental nature of words and therefore impact on the development of PA, especially in the early stages. Conversely, good representations may be necessary but not sufficient for good PA which will also build on foundations such as phonological working memory and clear speech output.

The data support the usefulness of the QPR task as a screening tool in Preprimary. It may be cost-effective to administer the QPR task to all children in Preprimary and then use PA tests with those children who perform poorly on the QPR task, i.e. those falling in the bottom quartile. The QPR task is quick to administer and may be administered by a person with minimal training. In addition,

results are analysed electronically. Thus, the task can be administered efficiently to large numbers of children.

Implications for intervention

The use of PA measures has become increasingly popular in Preprimary and early school programs to identify children at risk of literacy difficulties, and therefore to assist in making decisions about how to allocate shrinking clinical and teaching resources to minimize literacy difficulties in later years. The QPR task, described in detail in this article, adds value to a task battery in providing us with more information about a child's developing phonological representations and therefore informing classroom intervention. If a child evidences poor PA yet performs well on the QPR task, the focus of the classroom program and intervention would be best placed on 'awareness' — the metalinguistic skills of reflecting on segmenting/blending/manipulating sounds in words. In contrast, a child demonstrating poor PA and poor QPR would require intervention goals targeted at establishing clear and accurate representations and fixing up existing fuzzy ones (lexical restructuring) in parallel with PA work and literacy based goals. Gathering information about the quality of a child's underlying phonological representations as well as their PA may allow us to fine tune or subgroup children, and allow more specifically targeted intervention programmes, based on this knowledge.

Future directions

Having explored the development of phonological representations in the early years for a mainstream sample, the study is continuing on two fronts:

- An evaluation of the predictive validity of the QPR in identifying mainstream children at risk for literacy difficulties.
- An examination of the development of underlying representations in the population of children with specific language impairment. This project has recently completed the first stage of data collection on 70 children with specific language impairment in their Preprimary year. These children will also be followed up in Year 2 in 2008.

Acknowledgements

This paper reported part of a larger project funded by the Department of Education and Training, Western Australia. The authors would like to thank the children, families and schools involved.

References

- BOADA, R. and PENNINGTON, B., 2006, Deficient implicit phonological representations in children with dyslexia. *Journal of Experimental Child Psychology*, **95**, 153–193.
- CARROLL, J. M. and SNOWLING, M. J., 2004, Language and phonological skills in children at high risk of reading difficulties. *Journal of Child Psychology*, **45**, 631–640.

- CATTS, H. W., FEY, M. E., ZHANG, X. and TOMBLIN, J. B., 2001, Estimating the risk of future reading difficulties in kindergarten children: a research-based model and its clinical implementation. *Language Speech and Hearing Services in Schools*, **32**, 38–50.
- CATTS, H., GILLESPIE, M., LEONARD, L., KAIL, R. and MILLER, C., 2002, The role of speed of processing, rapid naming and phonological awareness in reading achievement. *Journal of Learning Disabilities*, **35**, 509–524.
- CATTS, H. and KAMHI, A., 1999, *Language and Reading Disabilities* (Boston, MA: Allyn & Bacon).
- CLAESSEN, M., LEITÃO, S., HEATH, S., FLETCHER, J. and HOGBEN, J., 2004, *Phonological Representations: A Window Into the Lexicon?* (Brisbane: International Association of Logopaedics and Phoniatrics).
- CROSBIE, S., DODD, B. and HOWARD, D., 2002, Spoken word comprehension in children with SLI: a comparison of three case studies. *Child Language Teaching and Therapy*, **18**, 190–212.
- DODD, B. and GILLON, G., 2001, Exploring the relationship between phonological awareness, speech impairment, and literacy. *Advances in Speech–Language Pathology*, **3**, 139–147.
- EDWARDS, J., BECKMAN, M. E. and MUNSON, B., 2004, The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language and Hearing Research*, **47**, 421–436.
- ELBRØ, C., 1998, When reading is 'readn' or somthn. Distinctness of phonological representations of lexical items in normal and disabled readers. *Scandinavian Journal of Psychology*, **39**, 149–153.
- FAWCETT, A. and NICOLSON, R., 1994, Naming speed in children with dyslexia. *Journal of Learning Disabilities*, **27**, 641–646.
- FELTON, R. and BROWN, I., 1990, Phonological processes as predictors of specific reading skills in children at risk for reading failure. *Reading and Writing*, **2**, 39–59.
- FOWLER, A., 1991, How early phonological development might set the stage for phoneme awareness. In S. Brady and D. Shankweiler (eds), *Phonological Processes in Literacy: A Tribute to Isabelle Y. Liberman* (Hillsdale, NJ: Lawrence Erlbaum Associates), pp. 97–117.
- GILLON, G. T., 2004, *Phonological Awareness: From Research to Practice* (New York, NY: Guilford).
- GROSJEAN, F., 1980, Spoken word recognition processes and the gating paradigm. *Perception and Psychophysics*, **28**, 267–283.
- HEATH, S., CLAESSEN, M., FLETCHER, J., HOGBEN, J. and LEITÃO, S., 2006a, Catch them before they fall: Cost effective identification of students at-risk for literacy problems. Paper presented at the Speech Pathology Australia National Conference, Freemantle, Western Australia.
- HEATH, S., FLETCHER, J. and HOGBEN, J., 2006b, *Catch Them Before They Fall 2003–2005; Cost Effective Screening for Children At-Risk for Literacy Problems*. Report to the Department of Education and Training, Western Australia. The University of Western Australia, Perth, WA.
- HEATH, S. M. and HOGBEN, J. H., 2004, Cost-effective prediction of reading difficulties. *Journal of Speech, Language and Hearing Research*, **47**, 751–765.
- HESKETH, A., 2001, Phonological awareness, speech impairment and literacy: the missing link. *Advances in Speech Language Pathology*, **3**, 155–158.
- HOGAN, T., CATTS, H. and LITTLE, T., 2005, The relationship between phonological awareness and reading: implications for the assessment of phonological awareness. *Language, Speech, and Hearing Services in Schools*, **36**, 285–293.
- LEITÃO, S., 2003, Angela's story: applying psycholinguistic principles to spelling and word learning. *ACQuiring Knowledge in Speech, Language and Hearing*, **5**, 114–117.
- LEITÃO, S. and FLETCHER, J., 2004, Literacy outcomes for students with speech impairment: long-term follow-up. *International Journal of Language and Communication Disorders*, **39**, 245–256.
- LEITÃO, S., FLETCHER, J. and HOGBEN, J., 2000, Speech impairment and literacy difficulties: underlying links. *Australian Educational and Developmental Psychologist*, **17**, 63–75.
- LIBERMAN, I. and SHANKWEILER, D., 1985, Phonology and the problems of learning to read and write. *Remedial and Special Education*, **6**, 8–17.
- LOCKE, J. L., 1980, The inference of speech perception in the phonologically disordered child. *Journal of Speech and Hearing Disorders*, **33**, 431–467.
- LONIGAN, C., BURGESS, S. and ANTHONY, J., 2000, Development of emergent literacy and early reading skills in preschool children: evidence from a latent-variable longitudinal study. *Developmental Psychology*, **36**, 596–613.
- MAILLART, C., SCHELSTRAETE, M. and HUPET, M., 2004, phonological representations in children with SLI: a study of French. *Journal of Speech, Language, and Hearing Research*, **47**, 187–198.
- METSALA, J. and WALLEY, A., 1998, Spoken vocabulary growth and the segmental restructuring of lexical representations: precursors to phonemic awareness and early reading ability. In J. Metsala and

- L. Ehri (eds), *Word Recognition in Beginning Literacy* (London: Lawrence Erlbaum Associates), pp. 89–120.
- MUNSON, B., EDWARDS, J. and BECKMAN, M. E., 2005, Relationships between nonword repetition accuracy and other measures of linguistic development in children with phonological disorders. *Journal of Speech, Language and Hearing Research*, **48**, 61–78.
- NATHAN, L., STACKHOUSE, J., GOULANDRIS, N. and SNOWLING, M. J., 2004, The development of early literacy skills among children with speech difficulties: a test of the ‘critical age hypothesis’. *Journal of Speech, Language, and Hearing Research*, **47**, 377–392.
- NEILSON, R., 2003, *Sutherland Phonological Awareness Test — Revised* (Jamberoo, NSW: Language Speech and Literacy Services).
- PRING, T., 2005, *Research Methods in Communication Disorders* (London: Whurr).
- SNOWLING, M., 2000a, *Dyslexia* (Oxford: Blackwell).
- SNOWLING, M., 2000b, Language and literacy skills: who is at risk and why? In D. V. M. Bishop and L. B. Leonard (eds), *Speech and Language Impairments in Children: Causes, Characteristics, Intervention and Outcome* (Hove: Psychology Press), pp. 245–260.
- SNOWLING, M., VAN WAGTENDONK, B. and STAFFORD, C., 1988, Object-naming deficits in developmental dyslexia. *Journal of Research in Reading*, **11**, 67–85.
- STACKHOUSE, J. and WELLS, B., 1997a, *Children’s Speech and Literacy Difficulties, A Psycholinguistic Framework* (London: Whurr).
- STACKHOUSE, J. and WELLS, B., 1997b, How do speech and language problems affect literacy development? In C. Hulme and M. Snowling (eds), *Dyslexia: Biology, Cognition and Intervention* (London: Whurr), pp. 182–211.
- STACKHOUSE, J. and WELLS, B., 2001, *Children’s Speech and Literacy Difficulties 2: Identification and Intervention* (London: Whurr).
- SUTHERLAND, D. and GILLON, G., 2005, Assessment of phonological representations in children with speech impairment. *Language Speech and Hearing Services in Schools*, **36**, 294–310.
- SUTHERLAND, D. and GILLON, G., 2007, Development of phonological representations and phonological awareness in children with speech impairment. *International Journal of Language and Communication Disorders*, **42**, 229–250.
- SWAN, D. and GOSWAMI, G., 1997, Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, **66**, 18–41.
- VITEVICH, M. S. and LUCE, P. A., 1999, Probabilistic phonotactics and neighbourhood activation in spoken word recognition. *Journal of Memory and Language*, **40**, 374–408.
- WAGNER, R., TORGESON, J. and RASHOTTE, C., 1994, Development of reading-related phonological processing abilities: new evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, **30**, 73–87.
- WALLEY, A., 1993, The role of vocabulary development in children’s spoken word recognition and segmentation ability. *Developmental Review*, **13**, 286–350.
- WESSELING, R. and REITSMA, P., 2001, Preschool phonological representations and development of reading skills. *Annals of Dyslexia*, **51**, 203–229.
- WOLF, M. and GREIG BOWERS, P., 1999, The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, **91**, 415–438.

Appendix 1

Item	Pseudo-words	
Training A: Boomerang	Bormerang	(bɔmərəŋ)
	Booberang	(bubərəŋ)
	Poomerang	(pumərəŋ)
	Boonernang	(bunərəŋ)
	Boomerong	(bumərɔŋ)
	Bumerang	(bɔmərəŋ)
Training B: Ambulance	Armbulance	(ambjuləns)
	Ampulance	(æmpjuləns)
	Anbulance	(ænbjuləns)
	Ammulance	(æmjuləns)
	Ambulornce	(æmbjulɔns)
	Umbulance	(ʌmbjuləns)
1. Helicopter	Helicobter	(helikɔbtɐ)
	Helicopter	(helikɔptɐ)
	Hekilopter	(hekilɔptɐ)
	Hewicopter	(hewikɔptɐ)
	Hilicopter	(hilikɔptɐ)
	Helicopter	(helitɔptɐ)
2. Telescope	Telescop	(teləskɔp)
	Teleslope	(teləslɔp)
	Tilascope	(tiləskɔp)
	Telescobe	(teləskɔb)
	Tewescope	(tewəskɔp)
	Tolascope	(tɔləskɔp)
3. Dominoes	Dominoz	(dɔminɔz)
	Domanoes	(dɔmənɔuz)
	Duminoes	(dʌminɔuz)
	Tominoes	(tɔminɔuz)
	Domisoes	(dɔmisɔuz)
	Domimoes	(dɔmimɔuz)
4. Crocodile	Crocodill	(krɔkɔdɪl)
	Crocotile	(krɔkɔtɪl)
	Cocodile	(kɔkɔdɪl)
	Cracodile	(krækɔdɪl)
	Crookadile	(krɔkɔdɪl)
	Crotodile	(krɔtɔdɪl)
5. Television	Teelevision	(tilɔvɪzən)
	Delevision	(delɔvɪzən)
	Tesevision	(tesɔvɪzən)
	Televisiom	(telɔvɪzəm)
	Televusion	(telɔvu:zən)
	Tilavision	(tilɔvɪzən)
6. Hippopotamus	Hipapitamus	(hipɔpɔtɪməs)
	Hitopotamus	(hitɔpɔtɪməs)
	Hepapotamus	(hepɔpɔtɪməs)
	Hibopotamus	(hibɔpɔtɪməs)
	Hipopetamus	(hipɔpetɪməs)
	Hipopotapus	(hipɔpɔtɪpəs)
7. Binoculars	Binoculars	(bɪnɔkjuləz)
	Bimoculars	(bɪmɔkjuləz)
	Binogulars	(bɪnɔŋguləz)

Item	Pseudo-words	
8. Microphone	Binocliars	(bɪnɒkliəz)
	Binoculars	(bɪnækjuləz)
	Binukulars	(bɪnɒkjuləz)
	Macrophone	(mækɹəfoʊn)
	Micwophone	(maɪkwəfoʊn)
	Microphoon	(maɪkrəfoʊn)
	Migrophone	(maɪgrəfoʊn)
9. Rhinoceros	Microphon	(maɪkrəfɒn)
	Microphome	(maɪkrəfoʊm)
	Rhinoteros	(raɪnɒtərəs)
	Rhinuceros	(raɪnɒsərəs)
	Rhinoceroz	(raɪnɒsərəz)
	Rhimoceros	(raɪmɒsərəs)
	Rhinaceros	(raɪnæsərəs)
10. Spaghetti	Rhinorceros	(raɪnɒsərəs)
	Spagheki	(spəgeki)
	Basgetti	(bæzgeti)
	Spagiti	(spəgiti)
	Spaketti	(spəketi)
	Spaghotti	(spəgɒti)
	Pasgetti	(pəsgeti)

Appendix 2

(a) Percentiles for accuracy of correct rejections Preprimary ($n=235$) and Year 2 ($n=179$)

Raw score	Preprimary percentile	Year 2 percentile
4	<1	
5	1	
6	2	
8	2	
10	3	
12	3	
13	4	
15	5	<1
16	5	
17	6	
18	6	
20		1
21	7	
22	8	
23	8	
24	9	
25	9	
26	10	
27	11	
28	12	
29	14	2
30		2
31	16	3
32	17	

Raw score	Preprimary percentile	Year 2 percentile
33	19	
34	20	4
35	22	4
36	24	6
37	27	7
38	28	7
39	33	
40	35	8
41	40	10
42	43	12
43	49	16
44	54	18
45	57	22
46	62	25
47	67	29
48	74	36
49	80	44
50	82	49
51	87	58
52	91	66
53	94	76
54	96	84
55	99	88
56	>99	96
57		98
58		99
59		>99

Cumulative percentages are rounded to whole numbers.

(b) Percentiles for reaction time of correct rejections Preprimary ($n=235$) and Year 2 ($n=179$)

Reaction time (s)	Preprimary percentile	Reaction time (s)	Year 2 percentile
3.78	<1		
3.55–3.44	1		
3.36–3.28	2		
3.24–3.17	3		
2.96	4		
2.80–2.53	5		
2.49	6		
2.42–2.36	7		
2.27–2.25	8		
2.17–2.12	9		
2.10–2.09	10		
2.08–2.07	11	2.08	<1
2.04–2.01	12		
1.96	13		
1.94–1.91	14		
1.88–1.87	15		

Reaction time (s)	Preprimary percentile	Reaction time (s)	Year 2 percentile
1.85–1.81	17	1.86–1.83	1
1.80	18		
1.79–1.76	19		
1.75–1.73	21		
1.71–1.66	22		
1.65–1.61	23	1.64–1.56	2
1.60–1.59	24		
1.57	26		
1.54	27		
1.52	28	1.52–1.49	3
1.49–1.48	29		
1.46	30		
1.44	31	1.44–1.36	4
1.43	32		
1.40	33		
1.39	34		
1.38–1.37	36		
1.36	37		
1.34–1.33	38		
1.32	40	1.32	5
1.31	41	1.31	6
1.30–1.29	42		
1.28	44		
1.27	45		
1.26–1.24	46	1.26–1.25	7
1.23	48	1.24–1.23	8
1.22	49	1.22	9
1.21	50		
1.20	52		
1.18	53	1.19	10
1.17		1.17	11
1.16–1.15	54	1.16–1.14	12
1.13	56	1.13–1.12	13
1.11	57	1.11	14
1.10	59	1.10	15
1.09	60	1.09–1.08	16
1.08	62		
1.07–1.06	63	1.07–1.05	17
1.05	64		
1.04	66	1.04	18
1.02		1.02	19
1.01	67	1.01	20
1.00		1.00	21
0.99	68		
0.98	69		
0.97–0.96	70	0.96	22
0.94	71	0.95–0.94	24
0.93	72	0.93	25
0.92–0.91	74	0.92	26
		0.91	27
0.90–0.88	77	0.90	28
		0.89	30
		0.88	31
0.87	80	0.87	32
0.86	81	0.86	33

Reaction time (s)	Preprimary percentile	Reaction time (s)	Year 2 percentile
		0.85	35
0.84–0.83	83	0.84	37
		0.83	39
0.82	84	0.82	41
0.81	85	0.81	42
		0.80	44
0.79	86	0.79	45
0.78–0.77	87	0.78	46
		0.77	48
0.76	88	0.76	49
0.75–0.74	89	0.75	51
		0.74	54
0.72	90	0.72	55
0.71–0.66	92	0.71	58
		0.70	62
		0.69	63
		0.68	65
		0.67	66
		0.66	68
		0.65	69
0.64–0.61	94	0.64	70
		0.63	72
		0.62–0.61	74
0.60	95	0.60	76
0.59	96	0.59	77
		0.58	78
		0.56	79
0.55–0.54	97	0.55–0.54	80
		0.53	82
0.52–0.50	98	0.52	83
		0.51	85
		0.50	86
		0.49–0.47	87
		0.46	88
0.44	99	0.45–0.44	92
0.43	>99	0.43–0.42	93
		0.41–0.38	94
		0.37	96
		0.35	97
		0.33–0.27	98
		0.26	>99

Cumulative percentages are rounded to whole numbers.

Copyright of International Journal of Language & Communication Disorders is the property of Taylor & Francis Ltd and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.

Paper 2: Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language and Communication Disorders*, 45(4), 411-423.

Please note the error in table 4 where the bottom right hand corner is slightly misaligned.

This article was downloaded by: [Curtin University Library]

On: 8 September 2009

Access details: Access Details: [subscription number 909765423]

Publisher Informa Healthcare

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



International Journal of Language & Communication Disorders

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title-content=t713393930>

Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task

Mary Claessen^a; Suze Leitão^a; Nick Barrett^a

^a Psychology, Curtin Health Innovation Research Institute, Curtin University of Technology, Perth, WA, Australia

First Published on: 01 September 2009

To cite this Article Claessen, Mary, Leitão, Suze and Barrett, Nick(2009)'Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task',International Journal of Language & Communication Disorders,99999:1,

To link to this Article: DOI: 10.1080/13682820903111945

URL: <http://dx.doi.org/10.1080/13682820903111945>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Research Report

Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task

Mary Claessen, Suze Leitão and Nick Barrett

Psychology, Curtin Health Innovation Research Institute, Curtin University of Technology, Perth, WA, Australia

(Received 15 December 2008; accepted 9 June 2009)

Abstract

Background: The development of children's speech, language, and literacy skills is considered to build on a robust and intact speech-processing system, with normally functioning skills at all levels of input and output processing, as well as storage. There are a range of tasks available that assess input and output processing skills, however there are few tasks described in the literature that require a child to reflect on and analyse the internal structure of their own phonological representations.

Aims: This paper will describe the development of the Silent Deletion of Phonemes (SDOP) task. This task is designed to assess a child's ability to delete and manipulate sounds silently within their own stored representations while minimizing the impact of any output difficulties.

Methods & Procedures: The SDOP task was presented to 69 typically developing mainstream Year 2 children (aged 7;2–8;1 years) as part of a battery of phonological processing skills and literacy measures.

Outcomes & Results: Scores for the population of typically developing Year 2 children were normally distributed and above a basal level but not approaching ceiling. Performance on the SDOP was significantly correlated with other measures of phonological processing but not a measure of non-verbal ability. It was most highly correlated with the measure of phonological awareness as expected, as both tasks measure awareness of the internal structure of words. However, the SDOP provided more information about the accuracy and specificity of a child's underlying phonological representations. The SDOP explained a significant amount of concurrent variance in both reading and spelling performance beyond the variance accounted for by the predictors that have been used by researchers to date. In combination, the SDOP and rapid-naming measure accounted for 58.8% of variance in performance on the reading measure and 54.4% of variance in spelling performance.

Conclusions & Implications: The SDOP task appears to be a valid and reliable tool to assess the internal structure of a child's stored phonological representations. Profiling phonological representations allows clinicians to explore children's speech-processing skills which may be particularly useful with children with complex literacy difficulties.

Keywords: phonological representations, phonological awareness, assessment, literacy development.

What this paper adds

Many tasks currently used to assess the integrity of underlying phonological representations are confounded by requiring spoken output. In most tasks, the child is asked to reflect on the structure of a heard word, rather than reflecting on their own stored representation of a word. This paper will describe the development of the Silent Deletion of Phonemes (SDOP) task and provide data based on the use of this task with a group of typically developing 7-year-old children. The SDOP is designed to assess a child's ability to delete and manipulate sounds internally within their own stored representations of a word without requiring output. This allows us to 'open the window' further into the lexicon and measure the accuracy and integrity of the underlying phonological representation. Profiling both phonological awareness skills and a child's underlying phonological representations allows more informed goal-setting and intervention planning.

Address correspondence to: Mary Claessen, Psychology, Curtin University of Technology, GPO Box U1987, Perth, WA 6845, Australia; e-mail: M.Claessen@curtin.edu.au

Introduction

An intact speech-processing system, with strongly developing skills in input and output processing as well as lexical storage, provides a solid foundation for the development of children’s speech, language, and literacy skills (Chiat 2000, Dodd 1995, Stackhouse and Wells 1997). In contrast, compromised speech-processing skills underlie the difficulties experienced by many children in the areas of speech, language, and literacy. This population of children is known to be heterogeneous, consequently accurate profiling of the children’s skills is important both theoretically in terms of understanding their difficulties and practically, in

terms of maximizing the effectiveness of goal-setting and therapy (Baker *et al.* 2001, Hewlett *et al.* 1997).

Assessing strengths and weaknesses in order to set up hypotheses about a child’s profile requires that clinicians adopt a principled approach, in particular understanding the processing demands of their assessment tasks. The model described by Stackhouse and Wells (1997) provides a framework which allows a systematic hypothesis testing approach in assessment. The speech-processing profile based on this model (Figure 1) is a clinical tool which is used to ask questions about a child’s: (1) input processing or ability to decode speech signals (for example, using auditory discrimination tasks), (2) output processing or ability to

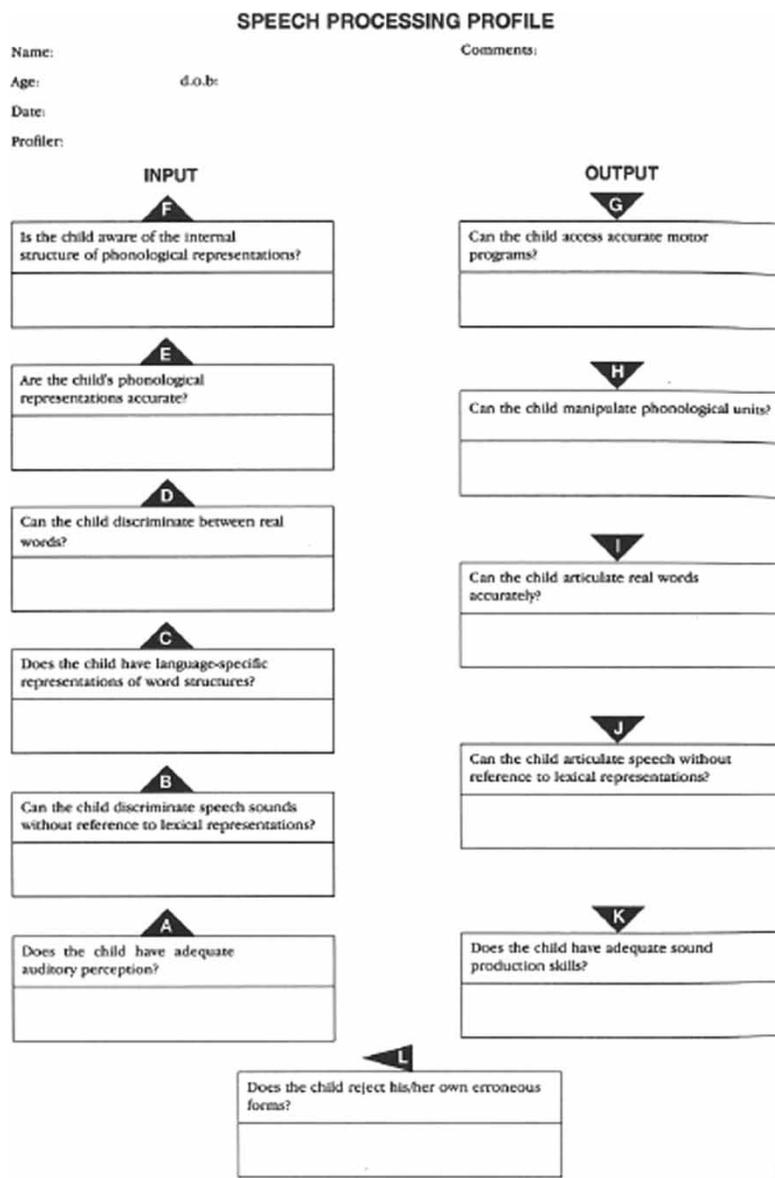


Figure 1. Speech-processing framework. Source: Stackhouse and Wells (1997), reproduced with permission.

encode and produce speech (for example, using non-word repetition tasks), and (3) underlying lexical storage or stored lexical representations (for example, naming pictures). On the left of the framework (questions A–F) assessment tasks require input processing, while on the right, assessment tasks that answer questions G–K require output. In addition, answering questions nearer the top of the framework requires lexical access while those nearer the bottom can be answered using tasks that do not require accessing stored linguistic knowledge (Stackhouse and Wells 1997, Stackhouse *et al.* 2007).

One of the challenges in assessment is gaining information about the storage of words in a child's long term memory without the confounding influence of speech (Chiat 2000). This requires the child to access the word phonology from their store without saying the words and make an internal judgement about the word. Such tasks can be of two types which are characterized by different input.

In one approach, often termed 'auditory lexical discrimination tasks', the child is asked to make a judgement based on comparing their own stored representation to a heard word. These tasks are said to answer the level E question on the Stackhouse and Wells speech-processing profile: 'Are the child's phonological representations accurate?' (Stackhouse and Wells 1997: 87). Examples include the speech production-perception task (Locke 1980), the phonological representation judgement task used by Sutherland and Gillon (2005), the Quality of Phonological Representations Task (Claessen *et al.* 2008), and a range of mispronunciation detection tasks described in Book 4 of *The Compendium of Auditory and Speech Tasks* (Stackhouse *et al.* 2007).

A second approach requires a child to access *and* analyse their own stored phonological representation of a word without hearing it spoken by either tester or child. Such tasks are said to answer the level F question on the Stackhouse and Wells speech-processing profile: 'Is the child aware of the internal structure of phonological representations?' (Stackhouse and Wells 1997: 90). Few tasks of this type are described in the literature, and most are informal. Examples include silent sorting of pictures according to initial sound, identification of pictures that rhyme and picking the odd one out based on the coda from a set of pictures. The task demands involve segmenting and blending, but do not require a child to delete or manipulate phonemes.

Given this potential gap in a theoretically driven assessment battery this paper describes the development of the Silent Deletion of Phonemes (SDOP) task. The SDOP was created as a silent deletion task to allow detailed investigation of a child's ability to reflect on

their own internal phonological representations of words, with the aim of further 'opening the window into the lexicon' (Claessen and Leitão 2004).

Phonological representations

As children learn new words representations of the sound-patterns of the words must be established in the lexical store (Gillon 2002). Children begin to form this representation on a very brief exposure, a process often referred to as 'fast mapping' (Fisher *et al.* 2001). During the word learning process children must encode words and be able to recognize them—even when spoken by different speakers (Fisher *et al.* 2001). In other words, the sound, or phonological, representations must be well enough defined to allow a child to match previously encoded sound patterns with new instances of the same sound in conversations, and thus allow for the acoustic variability that occurs both within and between speakers of the same language (Fisher *et al.* 2001). In addition, these sound based codes must be specified well enough to support the development of motor programs for the child to say the word (output) (Elbro *et al.* 1998, Vance *et al.* 2005). For example, the child must develop a representation of a word such as 'fist' which is well enough defined to allow the child to recognize the word as distinct from other similar sounding words like 'fits', 'fast', 'first' etc., even when spoken by a range of different speakers, including those with different accents and varying vocal qualities such as pitch. The phonological pattern of the word must also be encoded with enough specificity to allow the child to develop a motor program which will allow them to say the word clearly enough that it is easily perceived by listeners.

There is considerable evidence to suggest that phonological representations become more refined with development of vocabulary until explicit awareness is further facilitated by the acquisition of literacy (Maillart *et al.* 2004, Snowling and Hulme 1994, Stackhouse and Wells 1997). Metsala and Walley (1998) suggest that the process of lexical restructuring is gradual and word-specific. In typically developing language learners lexical restructuring eventually leads to words that have accurate and well segmented phonological representations associated with them.

In contrast, it has been proposed that low quality, poorly specified phonological representations can affect many aspects of language (Chiat 2001, Joanisse and Seidenberg 1998). For example, Chiat (2001) suggests that development in the areas of vocabulary and syntax relies heavily on phonological information being perceived and represented accurately. The work of Constable (2001) in the area of word-finding difficulties has suggested a strong relationship between lexical

retrieval and the precision of the phonological representations of the words. There is evidence that children with Specific Language Impairment (SLI) have imprecise word productions and poor non-word repetition skills which may be the result of poorly specified phonological representations and motor programmes (Catts and Kamhi 1999, Leitão 2003). Many researchers have hypothesized that well-developed phonological representations are important in the acquisition of literacy. Poorly specified representations will impact on the development of awareness of sounds within words, a skill known to support early literacy (Gillon 2004). In addition, poor quality representations may impact on a child's ability to use phonological information in reading and spelling (Sutherland and Gillon 2005). This is supported by the finding that children with dyslexia have been shown to have less mature phonological representations (Vellutino *et al.* 2004).

Assessing phonological representations

Drawing on the early work of Locke (1980), a number of lexical decision tasks have begun to re-emerge in the literature and clinical practice. These require a child to reflect on a phonological representation at a whole word level.

Crosbie *et al.* (2002) devised lexical decision tasks in which a child was asked to identify a string of speech sounds as a familiar word or an unfamiliar string, and judge whether a spoken word matched the semantic representation evoked by a picture. Three children with SLI who presented with similar profiles on standardized language assessments performed very differently on the experimental tasks tapping into processing skills. The three children all presented with receptive language difficulties at a single word level, however when underlying processing skills were considered it was found that one child presented with poor input processing skills and difficulties with lexical (real word) tasks, another had purely lexical level difficulties and the third had underlying semantic difficulties. This study highlights the importance of considering phonological processing skills in assessment.

Recently Sutherland and Gillon (2005) developed a task that required children to judge the accuracy of productions of multi-syllabic words. In this task children were shown a computer-generated picture of a multi-syllabic word. They then heard either the name of the picture, or a slightly modified production of the name. The children were required to point to either a happy face or a black cross to indicate the accuracy of the production they heard. Children with speech impairment performed significantly more poorly on this task than age-matched peers. Similarly, the Quality

of Phonological Representations (QPR) task (Claessen *et al.* 2008, Claessen and Leitão 2004) requires a child to look at a familiar picture, and then make a judgement about a production of the word. Children indicate their response using a computer mouse. Normative data on both accuracy and reaction time has been reported on this task for children aged 5 and followed up at 7 years, with data currently being collected for a group of participants with SLI in the same age range. Data for typically developing 3–7 year olds on a number of auditory lexical decision tasks are also presented in Stackhouse *et al.* (2007).

Whilst these tasks require a child to reflect on the accuracy of a heard word at a whole word level, there are few tasks described in the literature that require a child to reflect on and analyse the internal structure of their own phonological representations. Tasks of this nature usually use pictured material and neither the tester nor child says the word aloud. This approach ensures children are reflecting on their own stored representation of the lexical item rather than analysing a heard word. Such tasks could also be considered to place demands on working memory. A child's responses should also be silent to decrease the influence of output processing. Those tasks that have been reported require a child to segment or blend silently (for example, Phonological Assessment Battery subtest alliteration part 2 (Frederickson *et al.* 1997), or silently sort pictures according to initial/final sound (Stackhouse and Wells 1997).

We are not aware of any published task that requires a child to silently delete or manipulate sounds in words. The literature suggests that the ability to perform phoneme deletion tasks is a powerful predictor of literacy development (Gillon 2004, Stackhouse and Wells 1997). In terms of accessing underlying phonological representations, clinicians and researchers need to evaluate a child's ability to internally delete and manipulate sounds within their own stored representations. The Silent Deletion of Phonemes (SDOP) task was developed to allow the measurement of the child's ability to perform a deletion task using their own stored phonological representation, and in order to minimize the impact of output difficulties.

This paper will describe the development of the task, its design and implementation and report on the reliability and validity of the task. It will describe the performance of a sample of children from Year 2 in Western Australia (aged 7 years). This age group was selected based on normative data for traditional phoneme deletion tasks, as one which should provide a range of performance within the age group. In addition, given what the literature tells us about the contribution of well specified representations to the development of reading and spelling—this paper will

explore how well SDOP task performance explains the variance in concurrent literacy performance.

The following hypotheses were addressed:

- The measure of Silent Deletion of Phonemes will have adequate internal reliability.
- The measure of Silent Deletion of Phonemes will explain variance in reading and spelling beyond that explained by a set of predictor variables including phonological memory, rapid-naming and phonological awareness.

Method

Participants

Thirty-six female and 33 male typically developing Year 2 children were recruited from primary schools in the Perth metropolitan area (Western Australia) to participate in this research. Children were selected from two primary schools in middle socio-economic areas. The children ranged in age from 7;2 to 8;1 years at the time of testing. This study was approved by the Curtin University Human Research Ethics Committee and procedures complied with confidentially guidelines. Caregivers and participants provided informed consent to participate.

Exclusion and inclusion criteria

A parent/teacher questionnaire was used to ensure participants were typically developing, i.e. no evidence of significant hearing, vision, behavioural, language, educational or medical issues.

Measures

Measures included were the SDOP task (described in a subsequent section), as well as measures of phonological processing, including phonological awareness, phonological short term memory and rapid automatized naming, literacy, and working memory (Table 1). All were administered and scored according to the standard test protocols.

SDOP task development

The SDOP task is a computer administered task which consists of 35 pictured items as follows:

- Five items where one part of a compound word is deleted (for example, starfish—star).
- Five items where the initial phoneme is deleted (for example, pie—eye).
- Five items where the final phoneme is deleted (for example, cart—car).

- Five items where the initial phoneme of a word initial cluster is deleted (for example, bread—red).
- Five items where the final phoneme of a word initial cluster is deleted (for example, black—back).
- Five items where the initial phoneme of a word final cluster is deleted (for example, nest—net).
- Five items where the final phoneme of a word final cluster is deleted (for example, lamp—lamb).
- Two training items precede the test items.

Items were selected from a large pool of imageable words familiar to young children. In addition, the phonological structure of each potential item allowed a real word to remain once a syllable or phoneme was deleted. All pictures were obtained from copyright free electronic images. Potential items were piloted on eight Year 2 children to ensure the stimuli were easily recognized and the vocabulary known by children of that age. See appendix A for a complete list of items.

The task is administered over two sessions, one week apart. In session 1 the children are asked to identify each picture used in the task. If a picture is not recognized correctly, the item is taught by telling the child the name of the picture. At the end of session 1, the children are then re-asked to name these pictures.

The SDOP task is administered in session 2. The SDOP task uses a laptop computer to present children with a picture, and a verbal instruction to think of the name of the picture but not to say it aloud. They are then asked to delete a syllable or phoneme from the word and choose the correct picture from an array of four. Children indicate their response with a mouse click within the same quarter of the page as the selected response. At no stage is the name of the picture spoken aloud by either the examiner or the child. Task instructions were digitally recorded by an Australian monolingual, female speaker, and stored as WAV files using Cool Edit software.

A computer program was written using Matlab to present each item randomly. Accuracy and reaction time data were collected for each item and stored for later analysis.

The 35 items were randomized across levels, and then administered to each child in the same order. For each item the child sees a picture on a computer screen but the name of the item is not said aloud by either the child or the examiner. The child is then asked to ‘look at this picture and think of the name of, but don’t say it out loud’, for example, switch (Figure 2). The name of each item is not said by either child or examiner during the task.

They are then asked ‘now what word would it make if I took away the XX sound’, for example, took away

Table 1. Measures included in task battery

Area	Measures	Information obtained	Score used for analysis
Phonological awareness	Sutherland Phonological Awareness Test—Revised (SPAT-R) (Neilson 2003)	Items 1–11 were administered to collect data about the participant's ability to perform blending, deletion and manipulation tasks. These tasks require a verbal response	Responses on each item were summed
Phonological short-term memory	Memory for digits and non-word repetition subtests from the Comprehensive Test of Phonological Processing (CTOPP) (Wagner <i>et al.</i> 1999)	Ability to repeat a sequence of numbers and a non-word that has been verbally presented	Phonological memory composite score was calculated as per the test manual
Rapid automatized naming	Rapid digit-naming and rapid letter-naming subtests from the Comprehensive Test of Phonological Processing (CTOPP) (Wagner <i>et al.</i> 1999)	Ability to retrieve rapidly the names of very familiar items—in this case digits and letters	Rapid-naming composite score was calculated as per the test manual
Working memory	The Competing Language Processing Task (CLPT) (Gaulin and Campbell 1994)	Ability to process and store simultaneously incoming information through the answering of yes/no questions and later recalling the last words in each set	Responses on each item were summed
Reading	Word Identification subtest and Passage Comprehension subtests from the Woodcock Reading Mastery Tests—Revised (Woodcock 1987)	Real word-reading. Passage Comprehension was completed to allow the calculation of a Short Form Reading Score	The Short Form Reading Score was calculated as per instructions in the manual
Spelling	The South Australian Spelling Test (SAST) (Westwood 1993)	Real word spelling	Responses on each item were summed
Non-verbal intelligence	The Block Design and Picture Completion subtests of the Weschler—III (Wechsler 1991)	Non-verbal thinking skills	The mean of the subtest standard scores was used to provide an indication of non-verbal intelligence

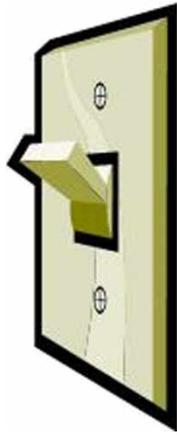


Figure 2. Stimulus item.

the 's' sound. They then see a computer screen consisting of four pictures—the correct response (witch), a semantic foil (light) and two phonological foils (swing and watch) (Figure 3). The child indicates their answer using the computer mouse.

Procedure

Participants were assessed by the researcher (first author) at their school over two sessions at least one week apart. All testing took place in a quiet area close to the child's classroom. Headphones were used for computer-based tasks to minimize the impact of

background noise. In the first session the CTOPP and SPAT-R tasks were administered, and phase one of the SDOP task was completed. In the second session reading and thinking skills measures were administered and the SDOP task completed. The spelling test was administered by the researcher on a group basis in the children's classroom. Rapid automatized naming and non-word repetition tasks were recorded using a lapel condenser microphone and Acer laptop computer. Results from the SDOP task were recorded digitally on the laptop computer.

Results

The means, standard deviations and distribution statistics for the SDOP and other measures are reported in Table 2. The measure of reading showed evidence of negative skewing ($skew = -3.01$) due to two cases with extremely low scores (43, $z = -3.53$ and 52; $z = -3.04$). These cases were not unusual for any other variables but did pose problems for subsequent regression analysis. There were no logical grounds for eliminating these cases and therefore a decision was made to truncate values of these cases to the next lowest value. The descriptive statistics and skew for reading reported in Table 2 are for the truncated cases. For all other variables the data were normally distributed with satisfactory skewness and kurtosis.

Table 3 shows the raw score associated with selected percentiles for the SDOP.

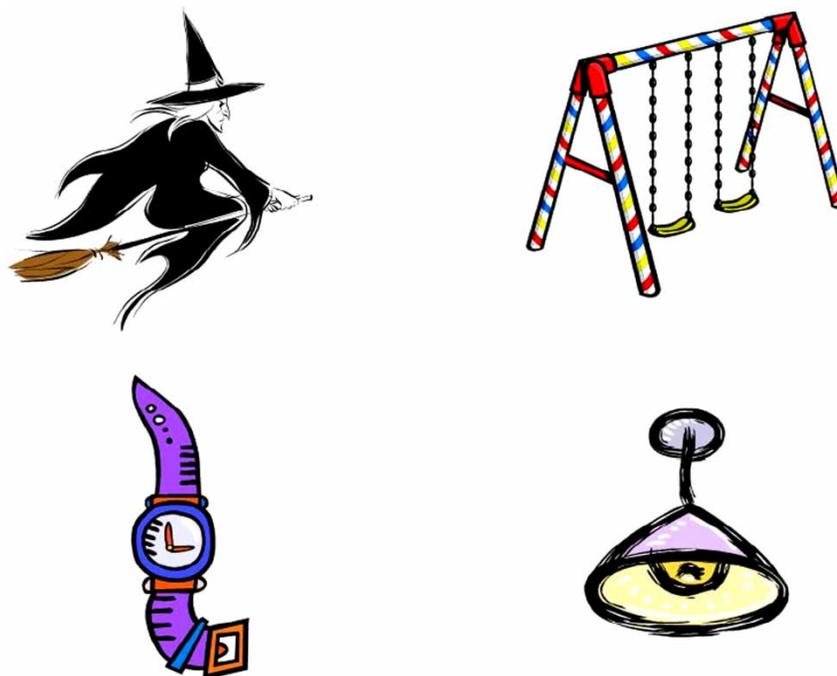


Figure 3. Response choices.

Table 2. Means, standard deviations, skewness and kurtosis for the variables in the hierarchical regression analyses

Measure	Mean	Standard deviation	Skewness	Kurtosis
SDOP	23.99	6.52	-1.19	-1.56
Phonological memory	98.66	12.00	0.96	-1.18
Rapid naming	103.60	14.06	0.99	0.76
CLPT	21.01	4.80	-0.13	-0.74
SPAT	36.39	4.05	-1.11	-1.03
Non-verbal IQ	10.37	2.44	0.65	0.82
Spelling	29.64	9.51	-0.32	-0.02
Reading	108.64	15.71	0.09	-0.55

Note: skewness and kurtosis are divided by the standard error

Table 3. Raw scores and their corresponding percentiles for the SDOP

Percentile	Raw score
16	17
25	18
50	24
75	30
84	31

Internal consistency of the SDOP

Reliability of the SDOP was estimated from internal consistency using coefficient alpha. Alpha was calculated at 0.845 which indicated a moderate level of internal consistency for the 35 items (Pring 2005).

Predictive utility of the SDOP

Hierarchical regression analysis investigated whether the new SDOP task adds to the explanation of criterion variance in reading and spelling beyond that explained by a set of predictor variables that include phonological memory, rapid-naming, CLPT and SPAT. This analysis was selected based on the theoretical grounds for entering the predictors in a specific order. In the

regressions reported here non-verbal IQ was entered first in order to control for this variable. On step two the group of predictors representing previous research into this area was entered to evaluate their contribution to understanding reading and spelling after controlling for non-verbal IQ. On the third step the SDOP was entered to evaluate whether it could add to the explanation of variance in reading and spelling above and beyond the other predictors.

The zero-order correlation matrix for the variables in the analyses is reported in Table 4. The validities for SDOP and the other predictors (phonological memory, rapid-naming, CLPT, SPAT) with each criterion variable (spelling, reading) are shown in the first two columns. Phonological memory, rapid-naming, CLPT, SPAT and SDOP are statistically related to both reading and spelling. An inspection of the validities showed the SDOP to have relatively high correlations with both reading ($r = 0.62$, $r^2 = 0.38$) and spelling ($r = 0.65$, $r^2 = 0.42$). High correlations with reading ($r = 0.64$, $r^2 = 0.41$) and spelling ($r = 0.52$, $r^2 = 0.27$) were also found for the rapid-naming predictor. When looking at the predictors in isolation, both the SDOP and rapid-naming explain a relatively higher proportion of the variance in both reading and spelling performance compared with the other predictors. At issue, however, is whether the SDOP is able to explain variance in reading and spelling above and beyond the variance that can be accounted for by rapid-naming and the other predictors in combination.

The correlation matrix also shows to what extent the SDOP shares variance with the other predictors. The SDOP was highly correlated with performance on the SPAT-R—a measure of phonological awareness. It was also significantly correlated with the phonological memory and rapid-naming composite scores and the measure of working memory. These results attest to the concurrent validity of the SDOP with measures of phonological awareness and memory. The SDOP also has divergent validity since it was not statistically correlated with the measure of non-verbal intelligence.

Table 4. Zero-order correlation matrix for the criterion (spelling, reading), predictor (phonological memory, Rapid naming, CLPT, SPAT, SDOP) and control (non-verbal IQ) variables in the hierarchical regression analyses

Measure	1	2	3	4	5	6	7	8
1. Spelling	–	0.80***	0.40**	0.52***	0.29*	0.48***	0.65***	0.20
2. Reading		–	0.47***	0.64***	0.25*	0.50***	0.62***	0.20
3. Phono memory			–	0.25*	0.32**	0.41**	0.12	
4. Rapid naming	–	0.25*	0.38**	–	0.09			
5. CLPT					–	0.37**	0.35**	0.33**
6. SPAT						–	0.63***	0.15
7. SDOP							–	-0.22
8. Non-verbal IQ								–

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed).

The magnitude of the linear association between the SDOP and the SPAT-R was within the range expected and reflects the less than perfect reliability of these measures as well as the different methods of data presentation and type of response required. In addition, the result is consistent with the SDOP tapping into skills not assessed by measures of phonological awareness.

Separate hierarchical multiple regression analyses were performed on each criterion variable at an adjusted alpha level of 0.025. The models were evaluated for heterogeneity of variance, residual outliers, outliers on the combination of predictors, tolerance and multicollinearity. The problems and their effects are reported for the respective analysis.

Prediction of reading

Table 5 reports the results of the hierarchical regression with reading as the criterion variable. On the first step non verbal IQ was entered as a control variable and did not explain statistically significant variance in reading, $F(1,64) = 2.671, p = 0.107 (r^2 = 0.040)$. At the second step the measures of phonological memory, rapid-naming, working memory (CLPT) and phonological awareness (SPAT) were entered. In combination these variables explained a statistically significant proportion of incremental variance, $F_{\text{change}}(4,60) = 18.128, p < 0.0001 (r^2_{\text{change}} = 0.525)$.

The model on the step 2 revealed that rapid-naming $t(60) = 5.310, p < 0.0001, sr^2 = 0.20$, explained statistically significant unique variance as indexed by the semi-partial correlation squared (sr^2). In addition,

Table 5. Hierarchical regression for the predictors (phonological memory, Rapid naming, CLPT, SPAT, SDOP) and control (non-verbal IQ) variables on the criterion variable of reading

Variable	B	SE	B
<i>Step 1</i>			
Non-verbal IQ	1.32	0.81	0.20
<i>Step 2</i>			
Non-verbal IQ	0.74	0.59	0.11
Phono memory	0.37	0.13	0.28*
Rapid naming	0.57	0.11	0.49***
CLPT	-0.32	0.33	-0.10
SPAT	0.88	0.39	0.23
<i>Step 3</i>			
Non-verbal IQ	0.42	0.56	0.06
Phono memory	0.30	0.12*	0.23*
Rapid naming	0.52	0.10	0.46***
CLPT	-0.38	0.31	-0.11
SPAT	0.17	0.42	0.04
SDOP	0.91	0.27	0.37**

Note: For the model with the outliers truncated; $R^2 = 0.04$ for Step 1 ($p > 0.025$); $\Delta R^2 = 0.525$ for Step 2 ($p < 0.001$); $\Delta R^2 = 0.069$ for Step 3 ($p < 0.01$). * $p < 0.025$, ** $p < 0.01$, *** $p < 0.001$.

phonological memory explained a statistically significant portion of unique variance, $t(60) = 2.969, p = 0.004, sr^2 = 0.064$.

On the third step, the SDOP was entered and added a statistically significant proportion of incremental variance, $F_{\text{change}}(1, 59) = 11.164, p = 0.001, r^2_{\text{change}} = 0.069$. In the final model, rapid-naming accounted for the largest proportion of unique variance ($sr^2 = 0.171$). These results suggest that SDOP is an important predictor of reading and that rapid-naming and the SDOP measure different aspects of reading. Phonological memory also accounted for unique variance in the final model, $t(59) = 2.515, p = 0.015 (sr^2 = 0.039)$. The effect of entering rapid-naming and the SDOP in combination on the final step was also examined. In combination these predictors accounted for an additional 0.273 of the variance in reading, $F(2,59) = 22.068, p = 0.0001$. The zero-order effects for the rapid-naming and SDOP tasks in combination (i.e. without partialling out the effects of the other predictors) were also examined and showed that these two tasks in combination accounted for 58.8% of the variance in reading scores.

Prediction of spelling

Table 6 reports the results of the hierarchical regression with spelling as the criterion variable. On the first step non verbal IQ was entered as a control variable and did not explain statistically significant variance in spelling, $F(1,64) = 2.106, p = 0.152 (r^2 = 0.032)$. At the second step the measures of phonological memory, rapid-naming, working memory (CLPT) and

Table 6. Hierarchical regression for the predictors (phonological memory, rapid naming, CLPT, SPAT, SDOP) and control (non-verbal IQ) variables on the criterion variable of spelling

Variable	B	SE	B
<i>Step 1</i>			
Non-verbal IQ	0.70	0.48	0.17
<i>Step 2</i>			
Non-verbal IQ	0.35	0.41	0.09
Phono memory	0.17	0.09	0.21
Rapid naming	0.24	0.07	0.36**
CLPT	-0.01	0.23	-0.04
SPAT	0.65	0.27	0.28*
<i>Step 3</i>			
Non-verbal IQ	0.01	0.37	0.02
Phono memory	0.10	0.08	0.13
Rapid naming	0.21	0.07	0.30**
CLPT	-0.13	0.21	-0.06
SPAT	0.06	0.28	0.03
SDOP	0.74	0.18	0.49***

Note: $R^2 = 0.032$ for Step 1 ($p < 0.025$); $\Delta R^2 = 0.384$ for Step 2 ($p > 0.001$); $\Delta R^2 = 0.128$ for Step 3 ($p < 0.001$). * $p < 0.025$, ** $p < 0.01$, *** $p < 0.001$.

phonological awareness (SPAT) were entered. In combination these variables explained a statistically significant proportion of incremental variance, $F_{\text{change}}(4,60) = 9.843$, $p < 0.0001$ ($r^2_{\text{change}} = 0.384$). An inspection of the model on the step two revealed that rapid-naming $t(60) = 3.31$, $p = 0.002$, $sr^2 = 0.11$) and the SPAT, $t(60) = 2.41$, $p = 0.019$, $sr^2 = 0.06$) explained statistically significant unique variance as indexed by the semi-partial correlation squared (sr^2). All other predictors were statistically redundant.

On the third step, the SDOP was entered and added statistically and practically significant incremental variance, $F_{\text{change}}(1, 59) = 16.604$, $p < 0.0001$, $r^2_{\text{change}} = 0.128$). In the final model, furthermore, SDOP accounted for the greatest proportion of unique variance ($sr^2 = 0.128$) making it the most important predictor of spelling ability in our sample. The only other predictor to explain unique variance was rapid-naming ($sr^2 = 0.076$). These results suggest that rapid-naming and the SDOP measure different aspects of spelling. All other predictors were redundant and did not add statistically significantly to the explanation of spelling. In total, 54.4% of the variance in spelling was accounted for. The remaining variance ($1 - R^2 = 0.456$) can be explained by the fact that the measures are not perfectly reliable and that the spelling task measures something unique that both the SDOP and the rapid-naming task fail to capture.

Discussion

The Silent Deletion of Phonemes (SDOP) task is a valid and reliable tool that allows clinicians and researchers to tap into the internal structure of a child's stored phonological representations. It is a useful tool for children in the early school years, with scores for a population of typically developing children aged between 7;2 and 8;1 years being normally distributed and above a basal level but not approaching ceiling. The task is delivered via a computer and thus administration can be easily standardized across children. Scoring is also completed electronically.

As expected, performance on the SDOP was correlated with measures of phonological awareness, rapid-naming and working memory. Furthermore, the lack of significance between the thinking skills measure and the SDOP suggest that the SDOP is not a measure of non-verbal ability. The SDOP was most highly correlated with performance on the SPAT-R (a measure of phonological awareness), as both tasks measure awareness of the internal structure of words. However, attenuation of the correlation between the two measures of internal structure is expected due to the different processing demands required by the tasks.

The SPAT-R assesses the child's ability to analyse words spoken by the tester by comparing them to their own stored representation (Stackhouse and Wells 1997), while the SDOP assesses the child's ability to reflect on their own stored phonological representation and the stimuli are not spoken by the tester (Stackhouse and Wells 1997). Thus, while the SDOP was correlated with a measure of phonological awareness it also provided more information about the accuracy and specificity of a child's underlying phonological representations.

We looked in more detail at the contribution of the different predictor variables to reading and spelling. The SDOP explained a significant amount of concurrent variance in both reading and spelling performance beyond the variance accounted for by the predictors that have been used by clinicians and researchers to date. Performance on the measures of reading and spelling were highly correlated. This is to be expected as both tasks draw on phonological awareness and phonic skills, decoding and access to a stored lexicon of sight words. However, reading and spelling differ on the presentation of material (orthographic for reading, and verbal for spelling measures).

In reading, the rapid automatized naming (RAN) task uniquely accounted for 17.1% of variance while the SDOP accounted for 6.9% of variance. RAN tasks measure the rapid retrieval of phonological codes from the lexicon. There is support in the literature for a strong relationship between the efficient and rapid access of stored phonological information and reading performance (Catts *et al.* 2002, Kail and Hall 1994). In combination the SDOP and rapid automatized naming of digits and letters together accounted for 27.3% of variance in performance on the reading measure after controlling for the effect of the other predictors. When we look at the zero-order effect in which the effect of the other predictors are not accounted for, we find that SDOP and rapid-naming in combination accounted for 58.8% of the variance in reading scores. These results suggest that when assessing a child experiencing reading difficulties the combination of SDOP and a RAN task would be useful when profiling strengths and weaknesses to inform therapy goals.

In spelling the SDOP accounted for 12.8% of unique variance, with RAN (7.6%) the only other variable to account for a significant amount of variance in spelling performance. In combination SDOP and rapid-naming of digits and letters accounted for 54.4% of variance in spelling performance again suggesting that their use in combination would be valuable.

The SDOP is a useful clinical tool in accounting for variance in both reading and spelling performance however it would also appear to have value in exploring

the accuracy of a child's phonological representations. The use of the SDOP in combination with a more traditional measure of phonological awareness such as the SPAT-R (Neilson 2003) which draws on a child's output would enable clinicians to explore a child's input processing skills, and phonological representations in more detail. For example, a child who performed well on the SDOP and poorly on the SPAT-R could be considered to have accurate, well-specified phonological representations but weaker output processing skills, perhaps as a result of earlier speech impairment. In this case therapy focusing on traditional phonological awareness tasks would be indicated. In contrast, poor performance on both the SDOP and a phonological awareness task might indicate poorly specified underlying phonological representations impacting on the ability to manipulate sounds. (This profile may also indicate output processing difficulties, however other tasks such as non-word repetition would be needed to confirm this.) In this case therapy focusing on developing accurate, well specified phonological representations would be indicated in addition to more traditional PA tasks.

Given the recognized processing difficulties in children with Specific Language Impairment (SLI) (Chiat 2000, Elbro *et al.* 1998) the SDOP will be a useful tool for clinicians and researchers to add to their clinical 'toolbox'. This silent deletion task allows more detailed investigation of a child's underlying knowledge of the phonological structure of words. The SDOP may be particularly valuable in the assessment of children who have output difficulties such as those who make a range of speech errors, and those using AAC devices. The task does not require an intact motor pathway as is the case with many other tasks which assess the quality of phonological representations.

While the SDOP has been shown to be a valid and reliable tool in typically developing children aged seven years more research is required to confirm its usefulness in children of other ages and those with a language impairment. The researchers are currently using the SDOP to explore the internal structure of phonological representations of a group of children with SLI. Both accuracy and reaction time data are being collected for children with SLI, as well as age-matched and language-matched peers.

Acknowledgements

The authors would like to thank Dr John Hogben for his valuable assistance in developing the task, and Dr Cori Williams for her support throughout this project. The authors would also like to thank the children, families, and schools involved in this project.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

- BAKER, E., CROOT, K., MCLEOD, S. and PAUL, R., 2001, Psycholinguistic models of speech development and their application to clinical practice. *Journal of Speech, Language and Hearing Research*, **44**, 685–702.
- CATTS, H., GILLESPIE, M., LEONARD, L., KAIL, R. and MILLER, C., 2002, The role of speed of processing, rapid-naming and phonological awareness in reading achievement. *Journal of Learning Disabilities*, **35**, 509–524.
- CATTS, H. and KAMHI, A., 1999, *Language and Reading Disabilities* (Boston, MA: Allyn & Bacon).
- CHIAT, S., 2000, *Understanding Children with Language Problems* (Cambridge: Cambridge University Press).
- CHIAT, S., 2001, Mapping theories of developmental language impairment: premises, predictions and evidence. *Language and Cognitive Processes*, **16**, 113–142.
- CLAESSEN, M., HEATH, S., FLETCHER, J., HOGBEN, J. and LEITÃO, S., 2008, Quality of phonological representations: a window into the lexicon? *International Journal of Language and Communication Disorders*, **44**, 121–144.
- CLAESSEN, M. and LEITÃO, S., 2004, Phonological representations: a window into the lexicon, Paper presented at the 26th World Congress of the International Association of Logopedics and Phoniatrics, Brisbane, Queensland, Australia.
- CONSTABLE, A., 2001, A psycholinguistic approach to word-finding difficulties. In J. Stackhouse and B. Wells (eds), *Children's Speech and Literacy Difficulties 2: Identification and Intervention* (London: Whurr), pp. 330–365.
- CROSBIE, S., DODD, B. and HOWARD, D., 2002, Spoken word comprehension in children with SLI: a comparison of three case studies. *Child Language Teaching and Therapy*, **18**, 190–212.
- DODD, B., 1995, *The Differential Diagnosis and Treatment of Children with Speech Disorder* (London: Whurr).
- ELBRO, C., BORSTROM, I. and PETERSEN, D. K., 1998, Predicting dyslexia from kindergarten: the importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, **33**, 36–60.
- FISHER, C., HUNT, C., CHAMBERS, K. and CHURCH, B., 2001, Abstraction and specificity in preschoolers' representations of novel spoken words. *Journal of Memory and Language*, **45**, 665–687.
- FREDERICKSON, N., FIRTH, U. and REASON, R., 1997, *Phonological Assessment Battery (PhAB)* (Windsor: NFER-Nelson).
- GILLON, G., 2002, Follow-up study investigating the benefits of phonological awareness intervention for children with spoken language impairment. *International Journal of Language and Communication Disorders*, **37**, 381–400.
- GILLON, G., 2004, *Phonological Awareness: From Research to Practice* (New York, NY: Guilford).
- HEWLETT, N., GIBBON, F. and COHEN-MCKENZIE, 1997, When is a velar an alveolar? Evidence supporting a revised psycholinguistic model of speech production in children. *International Journal of Communication Disorders*, **33**, 161–176.
- JOANISSE, M. F. and SEIDENBERG, M. S., 1998, Specific language impairment: a deficit in grammar or processing? *Trends in Cognitive Sciences*, **2**, 240–247.
- KAIL, R. and HALL, L., 1994, Processing speed, naming speed and reading. *Developmental Psychology*, **30**, 949–954.
- LEITÃO, S., 2003, Angela's story: applying psycholinguistic principles to spelling and word learning. *ACQuiring Knowledge in Speech, Language and Hearing*, **5**, 114–117.

- LOCKE, J. L., 1980, The inference of speech perception in the phonologically disordered child. *Journal of Speech and Hearing Disorders*, **45**, 431–467.
- MAILLART, C., SCHELSTRAETE, M. and HUPET, M., 2004, Phonological representations in children with SLI: a study of French. *Journal of Speech, Language, and Hearing Research*, **47**, 187–198.
- METSALA, J. and WALLEY, A., 1998, Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. Metsala and L. Ehri (eds), *Word Recognition in Beginning Literacy* (London: Lawrence Erlbaum Associates), pp. 89–120.
- NEILSON, R., 2003, *Sutherland Phonological Awareness Test—Revised* (Jamberoo, NSW: Language Speech and Literacy Services).
- PRING, T., 2005, *Research Methods in Communication Disorders* (London: Whurr).
- SNOWLING, M. and HULME, C., 1994, The development of phonological skills. *Philosophical Transactions of the Royal Society of London B*, **346**, 21–27.
- STACKHOUSE, J., VANCE, M., PASCOE, M. and WELLS, B., 2007, *The Compendium of Auditory and Speech Tasks. Children's Speech and Literacy Difficulties* (Chichester: Wiley).
- STACKHOUSE, J. and WELLS, B., 1997, *Children's Speech and Literacy Difficulties, A Psycholinguistic Framework* (London: Whurr).
- SUTHERLAND, D. and GILLON, G., 2005, Assessment of phonological representations in children with speech impairment. *Language Speech and Hearing Services in Schools*, **36**, 294–310.
- VANCE, M., STACKHOUSE, J. and WELLS, B., 2005, Speech production skills in children aged 3–7 years. *International Journal of Language and Communication Disorders*, **40**, 29–48.
- VELLUTINO, F. R., FLETCHER, J. M., SNOWLING, M. J. and SCANLON, D. M., 2004, Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, **45**, 2–40.
- WAGNER, R., TOREGESSEN, J. and RASHOTTE, C., 1999, *Comprehensive Test of Phonological Processes* (Austin, TX: PRO-ED).
- WESCHLER, D., 1991, *Weschler Intelligence Scale for Children—Third Revision* (New York, NY: Psychological Corporation).
- WESTWOOD, P., 1993, *The South Australian spelling test*. In *Spelling* (Seacombe Gardens, SA: Department for Education and Children's Services).
- WOODCOCK, R., 1987, *Woodcock Reading Mastery Test—Revised* (New York, NY: American Guidance Service).

Appendix A: Silent Deletion of Phonemes Task (SDOP)

Stimulus	Instruction	Target	Phono distractor	Phono distractor	Semantic distractor
<i>Training items</i>					
1. Teapot	Delete tea	Pot	Cot	Tea	Kettle
2. Earring	Delete ring	Ear	Ring	Beer	Head
<i>Syllable level</i>					
1. Football	Delete foot (1)	Ball	Wall	Foot	Basketball
2. Starfish	Delete fish (2)	Star	Car	Fish	Octopus
3. Eggcup	Delete cup (2)	Egg	Leg	Cup	Spoon
4. Cowboy	Delete boy (2)	Cow	Cloud	Boy	Sheep
5. Toothbrush	Delete tooth (1)	Brush	Bus	Tooth	Toothpaste
<i>Onset-rime</i>					
Tie	Delete t	Eye	Pie	Tyre	Hat
Feet	Delete f	Eat	Meat	Wheat	Shoe
Leg	Delete l	Egg	Peg	Log	Arm
Dice	Delete d	Ice	Mice	Dive	Game
Gate	Delete g	Eight	Plate	Game	Cage
<i>Phoneme—final sound</i>					
1. Cart	Delete t	Car	Dart	Heart	Horse
2. Beak	Delete k	Bee	E	Key	Bird
3. Sword	Delete d	Saw	Four	Door	Knight
4. Fork	Delete k	Four	Saw	Farm	Knife
5. Pies	Delete z	Pie	Eyes	Peas	Sauce
<i>Phoneme—WICI</i>					
1. Ski	Delete s	Key	C	Sky	Sled
2. Train	Delete t	Rain	Crane	Tray	Bus
3. Switch	Delete s	Witch	Swing	Watch	Light
4. Swing	Delete s	Wing	Ring	Swim	Slide
5. Block	Delete b	Lock	Black	Clock	Dice
<i>Phoneme—WICF</i>					
1. Bread	Delete r	Bed	Red	Head	Cake
2. Snail	Delete n	Sail	Nail	Snake	Beetle
3. Black	Delete l	Back	Sack	Block	Grey
4. Blocks	Delete l	Box	Lock	Socks	Toy
5. Clap	Delete l	Cap	Clip	Map	Hand
<i>Phoneme—WFCI</i>					
1. Sand	Delete n	Sad	Hand	Sack	Sand castle
2. Nest	Delete s	Net	Neck	Knot	Bird
3. Trains	Delete n	Trays	Hay	Tray	Buses
4. Pump	Delete m	Pup	Plum	Cup	Bike
5. Ghost	Delete s	Goat	Coat	Toast	Witch
<i>Phoneme WFCF</i>					
1. Lamp	Delete p	Lamb	Cap	Stamp	Table
2. Belt	Delete t	Bell	Bed	Head	Jeans
3. Gold	Delete d	Goal	Bowl	Foal	Silver
4. Shelf	Delete f	Shell	Bell	Well	Desk
5. Wink	Delete k	Wing	Pink	One	Blink

Paper 3: Claessen, M. & Leitão, S. (2012) Phonological representations in children with SLI. *Child Language Teaching and Therapy*, 28 (2), 211-224.

Please note the error on page 216 where the average difference in age between the SLI and age-matched participants is reported as 13 months rather than 1.3 months.

Child Language Teaching and Therapy

<http://clt.sagepub.com/>

Phonological representations in children with SLI

Mary Claessen and Suze Leitão

Child Language Teaching and Therapy 2012 28: 211

DOI: 10.1177/0265659012436851

The online version of this article can be found at:

<http://clt.sagepub.com/content/28/2/211>

Published by:



<http://www.sagepublications.com>

Additional services and information for *Child Language Teaching and Therapy* can be found at:

Email Alerts: <http://clt.sagepub.com/cgi/alerts>

Subscriptions: <http://clt.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

Citations: <http://clt.sagepub.com/content/28/2/211.refs.html>

>> [Version of Record](#) - May 2, 2012

[What is This?](#)

Phonological representations in children with SLI

Child Language Teaching and Therapy
28(2) 211–223

© The Author(s) 2012

Reprints and permission: sagepub.co.uk/journalsPermissions.nav

DOI: 10.1177/0265659012436851

clt.sagepub.com



Mary Claessen and Suze Leitão

Curtin University, Australia

Abstract

It has been hypothesized that children with specific language impairment (SLI) have difficulty processing sound-based information, including storing and accessing phonological representations in the lexicon. Tasks are emerging in the literature that provide a measure of the quality of stored phonological representations, without requiring a verbal response. This article describes the performance of children with specific language impairment (SLI) ($n = 21$), typically developing children matched for age ($n = 21$), and typically developing children matched for language ($n = 21$) on two measures of phonological representations – the Quality of Phonological Representations (QPR) and the Silent Deletion of Phonemes (SDOP) – and a measure of phonological awareness, the Sutherland Phonological Awareness Test: Revised (SPAT-R). As predicted the age-matched (AM) group demonstrated significantly better performance on all tasks than the SLI group. The AM group performed significantly better than the language-matched (LM) group on the SDOP and SPAT tasks, but not significantly differently on the QPR task. The SLI group performed significantly better than the LM group on both the SDOP and SPAT, but their performance on the QPR was significantly weaker than the LM group. The findings of this study provide support for the notion of lower quality phonological representations in children with SLI thus placing them at increased risk of ongoing language and literacy difficulties.

Keywords

assessment, phonological awareness, phonological representations, specific language impairment (SLI), speech processing

I Introduction

The challenge for speech and language therapists to become evidence based in their practice demands that we understand more about the nature of the underlying deficits with which our clients present. It is difficult, indeed potentially impossible, for us to provide cost-effective intervention until we understand more about the cause and specific nature of developmental speech and language impairments. This can be achieved if clinicians and researchers work together to study both

Corresponding author:

Mary Claessen, School of Psychology and Speech Pathology, Curtin Health Innovation Research Institute, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

Email: m.claessen@curtin.edu.au

the developmental trajectories of language skills and the underlying processing skills required to achieve language competence.

In the adult field clinicians have been using psycholinguistic models to profile clients' strengths and weaknesses and to derive theoretically driven goals for a number of years. Models such as the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) – which allows an analysis of the input and output processing of both spoken and written language – are useful in exploring the processing demands of language tasks at both the word and sentence level (Kay et al., 1996). One of the reasons that psycholinguistic approaches to assessment can be used successfully with the adult population is that the language system is assumed to have been intact and fully functioning prior to an incident.

There is evidence of emerging application of psycholinguistic frameworks to paediatric assessment/intervention with the work of Chiat (2000), and Stackhouse and Wells (1997). One difficulty in the paediatric population is that assumptions about the system cannot be made in the same way, because the language system is still developing and in most cases a weakness in language skills is developmental rather than the result of a neurological incident (Roy and Chiat, 2008). Thus in planning assessment and interpreting performance on assessment tasks, we need to consider both the processing demands of the individual task as well as the developmental level and experience of the child. In order to interpret assessment findings accurately it is important that we understand the development and processing demands of specific tasks. At this point such information is scarce and consequently clinicians and researchers must work together to 'construct task specific trajectories with hypothesized pathways' (Roy and Chiat, 2008: 5).

The first step in this process is to develop our understanding of such trajectories with typically developing children, in order to increase our understanding of typical language development. This in turn needs to be followed with studies of children with atypical language development such as specific language impairment (SLI), speech impairment and disorders on the autism spectrum.

1 Stackhouse and Wells' psycholinguistic framework

Stackhouse and Wells (1997) devised a theoretically driven and clinically applied psycholinguistic model of speech processing. In this model, the lexicon is described as consisting of phonological, semantic and syntactic representations, as well as a motor program (Stackhouse and Wells, 1997). As literacy is acquired an orthographic representation is also laid down. This model is unique in that it consists of three components: the speech processing profile (as seen in Figure 1), the model of speech processing and the developmental phase model (Stackhouse and Wells, 1997). The combination of these components facilitates theory driven assessment of the whole system, allowing both exploration of processing demands of specific tasks and developmental considerations.

The assessment framework allows clinicians to develop hypotheses about a client's speech processing skills in terms of speech input, lexical storage and speech output, and then design and/or draw on existing assessment tasks to test these hypotheses and plan theory-driven intervention. Assessment tasks are developed with consideration of the gradual development of the speech processing system and children's performance interpreted in terms of developmental phases of the unfolding system (Stackhouse and Wells, 1997).

2 Phonological representations

Phonological representations are the sound-based codes stored in the lexicon for each word (Anthony et al., 2010; Gillon, 2002). It is generally accepted that phonological representations are

SPEECH PROCESSING PROFILE

Name: _____ Comments: _____

Age: d.o.b: _____

Date: _____

Profiler: _____

INPUT	OUTPUT
F	G
Is the child aware of the internal structure of phonological representations? _____	Can the child access accurate motor programs? _____
E	H
Are the child's phonological representations accurate? _____	Can the child manipulate phonological units? _____
D	I
Can the child discriminate between real words? _____	Can the child articulate real words accurately? _____
C	J
Does the child have language-specific representations of word structures? _____	Can the child articulate speech without reference to lexical representations? _____
B	K
Can the child discriminate speech sounds without reference to lexical representations? _____	Does the child have adequate sound production skills? _____
A	
Does the child have adequate auditory perception? _____	
L	
	Does the child reject his/her own erroneous forms? _____

Figure 1 The speech processing profile: Children's speech and literacy difficulties: A psycholinguistic framework

Source: Stackhouse and Wells, 1997 (reproduced with permission from John Wiley and Sons)

initially a holistic articulatory gesture associated with the meaning of a word (Maillart et al., 2004; Snowling and Hulme, 1994). The lexical restructuring (Metsala and Walley, 1998) and segmentation (Fowler, 1991) hypotheses suggest that with the rapid increase in vocabulary during the preschool years, more finely grained phonological representations are developed and stored. As vocabulary continues to develop, so phonological representations become more specific, with lexical items segmented into increasingly smaller units. Precise, well-defined phonological representations are important for distinguishing between similar sounding lexical items, retrieving words and performing phonological awareness tasks (Fowler, 1991). It has been suggested that it may be more difficult to segment and manipulate low quality phonological representations (Elbro et al., 1998).

Phonological representations are of interest to both clinicians and researchers alike, as there is evidence to suggest that the establishment of precise and well-defined phonological representations is vital for achieving language competence and later for literacy acquisition (Bishop and Snowling, 2004).

3 *Phonological representations in specific language impairment*

It has been suggested that weaknesses in the establishment and maintenance of phonological representations is an underlying deficit in conditions such as specific language impairment, and dyslexia, as well as sub-groups of children with speech sound disorder (Pennington and Bishop, 2009). In fact the firmly established and long standing observation that children with SLI exhibit weakness carrying out nonword repetition tasks (Bishop and Snowling, 2004; Conti-Ramsden et al., 2001) and word learning tasks (Kan and Windsor, 2010) has led to speculation that difficulty forming and retrieving phonological representations may be an underlying deficit in SLI. The repetition of nonwords requires the formation, storage and retrieval of a new phonological representation, while learning new words requires the development of both phonological and semantic representations and the development of links between the two (Alt and Plante, 2006).

The relationship between, and co-existence of, SLI and dyslexia has been explored by a number of researchers with some proposing that children with dyslexia have more severe phonological difficulties than those with SLI (Catts et al., 2005). Other researchers have proposed that disorders such as these are a result of a range of risk and protective factors that may be shared (Pennington, 2006). However, in order to understand the role of phonological representations in SLI and related conditions it is vital that we develop a battery of discriminatory assessment tasks.

4 *Assessment of phonological representations*

A range of tasks such as nonword repetition, auditory lexical decision and gating tasks have been used to assess quality of phonological representations. For example, in Elbro et al. (1998) a child was required to correct a puppet's inaccurate productions of common words such as 'crocodile'. In 2007, Stackhouse et al. released a compendium of tasks to be used in conjunction with the speech processing model in order to facilitate interpretation of performance. This book provides examples of tasks mapped to the Speech Processing Profile for a range of developmental stages, and normative data where available. However to date there are only a limited number of tasks that measure the quality of a child's phonological representations (Level E on the framework 'Are the child's phonological representations accurate?'; Stackhouse and Wells, 1997). Tasks to assess Level F on the framework, 'Is the child aware of the internal structure of phonological representations?' (Stackhouse and Wells, 1997) are even more scarce. Assessment of these levels on the profile is

vital as they provide insight into a child's own stored phonological representation rather than the child's ability to judge, store or manipulate a word that they have heard.

Many assessment tasks involve both the processing of speech input and the production of a motor output response as well as accessing stored phonological representations. Interpretation of a child's performance can be confounded because it is difficult to isolate the locus of the breakdown. In an attempt to address this, researchers have begun to develop tasks that require a child to make judgements about the accuracy of multisyllabic word productions, and to provide responses that do not require output/verbal responses: the Quality of Phonological Representations task (QPR), (Claessen et al., 2009) and the Phonological Representation Accuracy Judgment task (Sutherland and Gillon, 2005). Tasks such as this assess the quality or precision of stored phonological representations at the whole-word level. In order to investigate the internal structure of underlying stored phonological representations, Claessen et al. (2010) developed the Silent Deletion of Phonemes Task (SDOP). This task requires a child to reflect on and analyse the internal structure of their stored phonological representation.

5 The current study

One of the major limitations in both research and clinical practice with children with SLI has been the lack of valid and reliable receptive measures of phonological representations. Tasks have been emerging in the literature, with indications of validity and reliability and normative data for typically developing children, however there has been little research into the performance of children with SLI.

Thus the aim of this article is to explore the quality of phonological representations in children with SLI, as compared to age-matched and language matched peers, and add to the evidence base to support informed clinical decision-making. The article will compare performance on two previously reported silent measures of phonological representations, to performances on a traditional phonological awareness test. One measure of phonological representations, the QPR, investigates the quality of stored phonological representations at the whole word level. The second task, the SDOP, aims to measure a child's ability to reflect on, and manipulate the internal structure of stored phonological representations. Both of these tasks are receptive measures of phonological representations, and do not require a verbal response. The specific hypothesis for this study is that children with SLI will perform significantly worse on measures of phonological representations and phonological awareness than age-matched and language-matched peers.

II Method

1 Participants

Approval for all aspects of this research was granted from the Curtin University Human Research Ethics Committee and the Western Australia Department of Education and Training Research and Planning Unit. Procedures complied with confidentiality guidelines and both caregivers and participants provided informed consent to participate.

Sixty-three children were recruited for this study (36 males, 27 females). All participants passed a hearing screen at 25 dB across the range 500–8,000 Hz; demonstrated intelligible speech as judged by an experienced Speech and Language Therapist; and appropriate pragmatic skills as judged by their classroom teacher. English was the first language for all participants in this study.

Twenty-one children with SLI were recruited from a language development school in Perth, Western Australia. To be included in this group participants were required to have nonverbal cognitive skills within the average range as measured by the Block Design and Picture Concepts subtests of the Wechsler Intelligence Scale for Children: Third revision (WISC-3) (Wechsler, 1991). Participants were also required to have a Core Language Standard Score of 85 or less on the Clinical Evaluation of Language Functioning: IV (CELF-IV) (Semel et al., 2003). The CELF-IV was selected as the reference measure for language skills as it has sensitivity and specificity of .83 and .90 respectively for the Core Language Score with the adopted cut-off of 1 standard deviation below the mean (Semel et al., 2006). Scoring of all formal measures (the CELF-IV, WISC-3; WPPSI-III,) followed the guidelines in the manual accompanying each test.

Twenty-one age-matched (AM) participants and 21 language-matched (LM) participants were recruited from a metropolitan primary school in Perth, with a similar socioeconomic profile to the Language Development Centre. All participants for these groups were required to have nonverbal cognitive skills within the average range as measured by the Block Design and Picture Concepts subtests of the WISC-3 (Wechsler, 1991) for the AM group, and the Block Design and Matrix Reasoning Subtests of the Wechsler Preschool and Primary Scale of Intelligence: Third edition (WPPSI-III) (Wechsler, 2004) for the younger LM group. Participants were also required to have a Core Language Standard Score of more than 85 on the CELF-IV (Semel et al., 2003).

Each SLI participant was matched to an AM participant by age in months and gender. The average difference in age between the SLI and AM participants was 13 months. Each SLI participant was matched to a LM participant by gender and receptive language skills as measured by raw score on the Concepts and Following Directions Subtest on the CELF-IV. The average difference in raw scores between the SLI and LM participants was .65. Participants were matched by gender to ensure the groups were as similar as possible. Participants' performance on selection measures are summarized in Table 1.

2 Measures

Each participant was assessed on two measures of phonological representations: the Quality of Phonological Representations Task (QPR) (Claessen et al., 2009) and the Silent Deletion of Phonemes Task (SDOP) (Claessen et al., 2010). These tasks were scored following the published guidelines. In addition each participant was assessed on a measure of phonological awareness, the Sutherland Phonological Awareness Test: Revised (SPAT-R) (Neilson, 2003a), which was scored according to the manual guidelines.

Table 1 Performance on participant selection tasks

Variable	SLI			AM			LM		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (months)	91.05	3.60	82–96	90.90	4.19	82–98	65.86	3.47	59–71
Cognitive skills ^a	9.81	1.65	8–13	10.43	1.62	8–13	9.86	1.63	8–13
Language skills ^b	69.90	11.34	45–85	101.19	6.95	90–115	101.43	9.32	85–117
Language matching score ^c	26.62	9.135	11–42	40.38	6.289	23–50	26.86	7.735	15–42

Notes: ^aCognitive skill is the mean of the subtest standard scores from the WISC-3, and WPPSI-III. ^bThe Language skills score is the Core Language Score obtained from the CELF-IV. ^cThe raw score on the Concepts and Following Directions subtest on the CELF-IV

a Quality of phonological representations task (QPR): The QPR task is an auditory lexical discrimination task where children are required to judge the accuracy of a production of multi-syllabic word. In this task children are presented with four correct and six incorrect productions of each of the 10 stimulus items (for a list of stimulus items, see Appendix 1). Incorrect productions were generated by varying either one consonant or one vowel in the stimulus item (for details, see Claessen et al., 2009). For the QPR the measure of Correct Rejections was adopted, based on the number of inaccurate productions that were judged to be inaccurate. This measure had been found to be more closely linked to measures of phonological awareness and literacy than to the total number of items completed correctly (Claessen et al., 2009). There is moderate internal consistency of .84 for the task with children of a similar age to the SLI sample in this research; however, as the QPR task is unique, concurrent validity has not yet been established (Claessen et al., 2009).

b Silent Deletion of Phonemes (SDOP) task: The SDOP requires children to look at a picture and perform a deletion task without either hearing the word said aloud or saying it aloud themselves. The child is provided with a verbal instruction and then asked to select the correct item from an array of four pictures presented on a computer screen (Claessen et al., 2010). For this task, each participant achieved a raw score, based on the number of items that were completed correctly. The SDOP was selected as there is a relative paucity of tasks available that assess ability to reflect on stored representations. There is moderate internal consistency of .845 for the 35 test items (Claessen et al., 2010) and a correlation of .63 with the SPAT-R (Neilson, 2003a). This correlation was deemed to be sufficient to demonstrate concurrent validity, particularly given the different methods of data presentation and nature of the response required (Claessen et al., 2010).

c Sutherland Phonological Awareness Test: Revised (SPAT-R): The SPAT-R (Neilson, 2003a) was selected as the measure of phonological awareness as it has reliable psychometric properties, and as it was developed in Australia test items and normative data were suitable for the participants in this study. The subtests of the SPAT-R require judgement, production, segmentation, blending and deletion of syllables, onsets, rimes and phonemes. There is strong internal consistency of .95 for the items in the SPAT-R (Neilson, 2003a) and a strong correlation of .86, with an alternate measure of phonological awareness, The Astronaut Invented Spelling Test (Neilson, 2003b).

3 Procedure

Each participant was assessed in a quiet, familiar environment within their school setting. All tasks were administered by the first author, a speech and language therapist experienced in working with school-age children. Tasks were administered over two sessions at least one week apart. In the first session the participant selection tasks were administered, and all items from the SDOP were named to ensure children were familiar with each item. In the second session, the SDOP task was completed and the QPR and SPAT-R administered. A Hewlett Packard laptop computer was used to administer the SDOP and QPR tasks. Headphones were used for these tasks to minimize the impact of background noise, and results were digitally recorded on the computer.

III Results

The means, standard deviations and percentile ranks for the QPR, SDOP and SPAT-R are shown in Table 2. Percentile ranks for the SDOP were obtained from the data provided in Claessen et al. (2010); for the QPR from the data provided in Claessen et al. (2009); and for the SPAT-R from the examiner's manual (Neilson, 2003a).

Table 2 Means, standard deviations and percentile ranks for measures of phonological representation

Measure	SLI			AM			LM		
	Mean	SD	Percentile	Mean	SD	Percentile	Mean	SD	Percentile
SDOP	17.77	5.97	16	23.81	6.05	50	12.29	4.28	n/a ^a
QPR	38.24	5.66	7	47.52	4.80	36	44.10	7.01	54
SPAT-R	40.00	9.67	28	46.76	5.81	54	17.86	7.64	20

Note: ^aNo normative data is available for this age group on the SDOP task.

A multivariate analysis of variance (MANOVA) was used to examine the differences between groups on the measures of phonological representation and phonological awareness. Prior to carrying out the MANOVA, the data were examined to ensure all assumptions were met. As all assumptions were supported by the data, the MANOVA was conducted. Results indicated there was a significant difference between the groups on the combined dependent variables, $F(6, 118) = 23.532$, $p < .001$, partial $\eta^2 = .543$.

Analysis of individual dependent variables, showed that the QPR variable was significantly different across groups, $F(2, 60) = 13.337$, $p < .001$, partial $\eta^2 = .308$. Post-hoc analysis using Tukey's HSD ($\alpha = 0.05$) revealed that the AM group ($M = 47.52$, $SD = 4.80$) performed significantly better than the SLI group ($M = 38.24$, $SD = 5.66$), and the LM group ($M = 44.10$, $SD = 7.01$) performed significantly better than the SLI group. The difference between the AM and LM groups was not significant. Effect size for these relationships were $d = 1.319$, $.832$, and $.487$ respectively, indicating moderate to large effect sizes.

The SDOP was significantly different across groups, $F(2, 60) = 23.088$, $p < .001$, partial $\eta^2 = .435$. Post-hoc analysis using Tukey's HSD ($\alpha = 0.05$) revealed that the SLI group ($M = 17.76$, $SD = 5.97$) scored significantly lower than the AM group ($M = 23.81$, $SD = 6.05$) and significantly higher than the language-matched group ($M = 12.29$, $SD = 4.28$). The difference between the AM and LM groups was also significant. Effect sizes of $d = .920$, $.8334$, and 1.754 respectively, indicating large effect sizes for these relationships.

The SPAT variable was also significant across groups, $F(2, 60) = 77.50$, $p < .001$, partial $\eta^2 = .721$. Post-hoc analysis using Tukey's HSD ($\alpha = 0.05$) revealed that the SLI group ($M = 40$, $SD = 9.67$) scored significantly lower than the AM group ($M = 46.76$, $SD = 5.81$) and significantly higher than the language-matched group ($M = 17.86$, $SD = 7.64$). The difference between the AM and LM groups was also significant. Effect sizes were $d = .72$, 2.35 , and 3.07 respectively, indicating large effect sizes for these relationships.

IV Discussion

This study aimed to explore the quality of phonological representations in children with SLI compared to age matched and language matched peers, and to add to the evidence base to support informed clinical decision-making. It was predicted that the children with SLI would perform significantly more poorly than the comparison groups on each of the measures

1 Summary of performance

As predicted, the AM group demonstrated significantly better performance on all tasks than the SLI group. The AM group also performed significantly better than the younger LM group on the

SDOP and SPAT tasks but not significantly differently on the QPR task. In contrast, the SLI group performed significantly better than the LM group on both the SDOP and SPAT tasks but significantly weaker than the LM group on the QPR task. This pattern was not predicted, and therefore differences between participant groups and the nature of the individual tasks must be considered.

2 Differences in groups

The SLI and AM groups consisted of children with an average age of 7;6 (7 years, 6 months) who were in their third year of formal schooling, while the LM group had an average age of 5;6 and were in their first year of formal schooling. This is important as not only were the LM participants two years younger than the other participants, but they had not received the same level of formal literacy instruction as the other groups. Given the strong evidence that phonological awareness (PA) skills and reading skills are highly correlated, early literacy instruction generally includes a significant PA component (Gillon, 2004), which must be considered in the interpretation of results. Thus we would expect the LM group, who are at an earlier developmental stage, to have weaker performance on tasks that draw on underlying PA skills and knowledge, as well as working memory, such as the SPAT-R and also the SDOP.

As expected the AM group performed significantly better than the LM group on each task, suggesting that their phonological processing skills are well established in the metaphonological phase of the speech processing model (Stackhouse and Wells, 1997), while the skills of the younger LM participants are still emerging in this phase. The performance of the SLI participants falls between that of the other two groups on the SDOP and SPAT-R; however, their performance on the QPR is worse than predicted and, thus, in addition to a developmental perspective, the processing routes for the individual tasks need to be considered.

3 Differences in demands of the tasks

According to the Stackhouse and Wells (1997) framework, each of the three experimental measures requires the use of different processing routes.

The QPR task aims to explore the quality of stored phonological representations and addresses the Level E question on the Stackhouse and Wells speech-processing profile (1997) ‘Are the child’s phonological representations accurate?’ This task requires input processing and judgement at the whole-word level, with the child required to compare the phonological forms provided to them by the speaker with the phonological representation that is activated from their own underlying semantic representation for the lexical item. On this task the SLI participants evidenced the weakest performance, with the difference between the SLI and both AM and LM groups being significant. These results suggest that the SLI children have more imprecise or ‘fuzzy’ phonological representations than either age-matched or language-matched peers and thus are more likely to accept ‘near misses’ as correct productions than either of the groups with typically developing language skills. This result is consistent with the recent findings of Marshall et al. (2010) who adopted a similar approach and found that children with SLI were more likely to accept words that were produced with phonological errors than either typically developing or dyslexic peers.

The SDOP corresponds to Level F on the Speech Processing Profile – ‘Is the child aware of the internal structure of phonological representations?’ (Stackhouse and Wells, 1997) – again requiring input, but not output processing. It can be considered an input PA task, where the child is required to analyse the internal structure of the word stored in their lexical representation. Items in the SDOP are presented randomly, and then scored. A score higher than 15 indicates the ability to

delete a phoneme from a consonant cluster (e.g. delete the /r/ sound from /bred/). On the SDOP, the AM group achieved a mean score of 23.81, demonstrating they are able to perform deletion at this complex level; the SLI group achieved a mean of 17.77 suggesting this ability is emerging; while the LM group achieved a mean of 12.29 suggesting they are able to delete at a single phoneme level, but are not yet able to delete phonemes from consonant clusters. On this input phonological awareness task, the AM group performed significantly better than the SLI children who in turn performed significantly better than the LM children, and thus a developmental pattern was observed.

The SPAT-R is a traditional measure of PA and thus addresses the Level H question: 'Can the child manipulate phonological units?' (Stackhouse and Wells, 1997). This task involves both input and output processing as the target items are presented verbally and the child is generally required to perform a metalinguistic analysis on an input phonological representation provided by the tester, create a motor program for output and formulate a verbal response. On this task, the AM children performed at the highest level, followed by the SLI group then the LM group, with the differences between each group significant. The LM group had significantly weaker PA skills than either the AM or SLI group. This finding is not surprising given the difference in both age and formal schooling between the LM group and the other groups. The SLI children did significantly better on the PA task than the LM children, and not as well as the AM children, which suggests both the developmental nature of PA and their emerging skill development in the metaphonological phase.

The difference in patterns of performance between the Level E task and the Level F and Level H tasks was unexpected. This finding suggests that perhaps children with SLI have difficulty laying down accurate phonological representations, but also that the quality of their semantic representations and the links between these representations in the lexicon may not be as well developed and this may influence their ability to judge the accuracy of spoken words. This observation is consistent with the proposal that the difficulty that children with SLI have in learning new words is due to 'difficulty creating and storing phonological representations of new words and establishing a strong link between those representation' (Gray and Brinkley, 2011: 870).

A further consideration is the role of working memory (WM) required in the QPR task, which involves holding the heard word in working memory while comparing it to the semantic and phonological representation of the word accessed by recognition of the picture. The WM difficulties of children with SLI have been established (Montgomery et al., 2010), and future studies should explore the potential influence on working memory on performance on the QPR and similar tasks.

4 Evaluation of the hypothesis

The hypothesis that children with SLI will have weaker phonological representations and phonological awareness than age-matched and language-matched peers received limited support. The SLI participants demonstrated significantly lower quality phonological representations than either the AM or LM participants. In contrast their PA skills, on the SPAT, fell between those of the age-matched group and the language-matched group. In addition, on the SDOP task, which draws on both underlying representations and PA, the SLI participants demonstrated skills that, while not as strong as the AM group, were significantly better than the LM group.

This finding supports suggestions that with a focus on PA skills in the early school years, children's PA skills can improve and underpin development through the metaphonological phase, allowing children to take advantage of phonological awareness and literacy instruction (Stackhouse and Wells, 1997). However, it also suggests that for children with SLI, improvement in PA as

occurs in traditional PA programs – based on a metalinguistic, predominantly output-based approach to therapy using task items presented to the child by a therapist – does not in turn necessarily lead to higher quality, more accurate stored phonological representations.

5 Importance of high quality phonological representations

Many researchers (Alt and Plante, 2006; Chiat, 2001; Gray, 2005) suggest that development in the areas of vocabulary and syntax relies heavily on phonological information being perceived and represented accurately in order to establish the strong links between semantic and phonological representations of words required to learn new words. The work of Stackhouse and Wells (1997) has emphasized the role of a strong and well-developed underlying speech processing system in processing phonological information and establishing the foundations for speech, language and ultimately literacy. Poor quality representations may also impact on a child's ability to use phonological information in reading and spelling (Sutherland and Gillon, 2005), and there is evidence to support the notion of less mature phonological representations in children with dyslexia (Boada and Pennington, 2006). Claessen et al. (2010) found significant correlations between performance on the SDOP and performance measures of spelling and reading in typically developing children, again providing support for the importance of high quality phonological representations for literacy.

The findings of this present study also provide support for the notion of lower quality phonological representations in children with SLI, thus placing them at increased risk of ongoing language and literacy difficulties.

6 Clinical implications

In recent times much emphasis has been placed on teaching children the metacognitive skills required to complete PA tasks, with the aim that this would in turn lead to better specified phonological representations and therefore improved literacy skills (Gillon, 2004). There is evidence that PA therapy is effective but results of studies designed to measure the effect of PA instruction on literacy acquisition have been inconsistent (Hesketh, 2010). Results of this study suggest that the focus on PA skills in the early school years does support the development of PA; however, in children with SLI their underlying phonological representations may remain significantly weaker than those of typically developing children.

In clinical practice, we must consider how to improve the quality and accuracy of phonological representations in children with SLI. Rees (2001) recommends that therapy should target and strengthen links in the lexicon. Hesketh (2010) cites one example of a study designed to target phonological representations directly. In this study by Rvachew et al. (2004) one group of children received intervention based on mispronunciation detection tasks in addition to standard speech and language therapy. This led to an improvement in detection of mispronunciations; however, there was no improvement in PA. While this avenue of research looks promising, further research is necessary to develop, and evaluate theory driven therapy that has been designed to develop PA skills while also aiming to improve underlying phonological representations and strengthen the links in the lexicon.

Acknowledgements

The authors acknowledge the contribution of the schools and children who took part in this study; thanks also to Cori Williams, John Hogben and Nick Barrett, who provided valuable support and assistance in the early stages of this project.

References

- Alt M and Plante E (2006) Factors that influence lexical and semantic fast mapping of young children with specific language impairment. *Journal of Speech, Language and Hearing Research* 49: 941–54.
- Anthony J, Williams J, Aghara R, Dunkelberger M, Novak M, and Mukherjee A (2010) Assessment of individual differences in phonological representation. *Reading and Writing* 23: 969–94.
- Bishop DVM and Snowling MJ (2004) Developmental dyslexia and specific language impairment: Same or different? *Psychological Bulletin* 130: 858–86.
- Boada R and Pennington B (2006) Deficient implicit phonological representations in children with dyslexia. *Journal of Experimental Child Psychology* 95: 153–93.
- Catts H, Adlof S, Hogan T, and Weismer S (2005) Are specific language impairment and dyslexia distinct disorders? *Journal of Speech, Language and Hearing Research* 48: 1378–96.
- Chiat S (2000) *Understanding children with language problems*. Cambridge: Cambridge University Press.
- Chiat S (2001) Mapping theories of developmental language impairment: Premises, predictions and evidence. *Language and Cognitive Processes* 16: 113–42.
- Claessen M, Leitão S, and Barrett N (2010) Investigating children's ability to reflect on stored phonological representations: The silent deletion of phonemes task. *International Journal of Language and Communication Disorders* 45: 411–23.
- Claessen M, Heath S, Fletcher J, Hogben J, and Leitão S (2009) Quality of phonological representations: A window into the lexicon? *International Journal of Language and Communication Disorders* 44: 121–44.
- Conti-Ramsden G, Botting N, and Faragher B (2001) Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry and Allied Disciplines* 42: 741–48.
- Elbro C, Borstrom I, and Petersen DK (1998) Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly* 33: 36–60.
- Fowler A (1991) How early phonological development might set the stage for phoneme awareness. In: Brady S and Shankweiler D (eds) *Phonological processes in literacy: A tribute to Isabelle Y. Liberman*. Hillsdale, NJ: Lawrence Erlbaum Associates, 97–117.
- Gillon G (2002) Phonological awareness intervention for children: From the research laboratory to the clinic. *ASHA Leader* 7(22): 15–19.
- Gillon G (2004) *Phonological awareness: From research to practice*. New York: The Guilford Press.
- Gray S (2005) Word learning by preschoolers with specific language impairment: Effect of phonological or semantic cues. *Journal of Speech, Language, and Hearing Science* 48: 1452–67.
- Gray S and Brinkley S (2011) Fast mapping and word learning by pre-schoolers with specific language impairment in a supported learning context: Effect of encoding cues, phonotactic probability and object familiarity. *Journal of Speech, Language and Hearing Research*, 54: 870–84.
- Hesketh A (2010) Metaphonological intervention: Phonological awareness therapy. In: Williams L, McLeod S, and McCauley R (eds) *Interventions for speech sound disorders in children*. Baltimore, MD: Brookes, 247–74.
- Kan P and Windsor J (2010) Word learning in children with primary language impairment: A meta-analysis. *Journal of Speech Language and Hearing Research* 53: 739–56.
- Kay J, Lesser R, and Coltheart M (1996) Psycholinguistic assessments of language processing in aphasia (PALPA): An introduction. *Aphasiology*, 10: 159–80
- Maillart C, Schelstraete M, and Hupet M (2004) Phonological representations in children with SLI: A study of French. *Journal of Speech, Language, and Hearing Research* 47: 187–98.
- Marshall C, Ramus F, and van der Lely H (2010) Do children with dyslexia and/or specific language impairment compensate for place assimilation?: Insight into phonological grammar and representations. *Cognitive Neuropsychology* 27: 563–86.
- Metsala J and Walley A (1998) Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In: Metsala J and Ehri L (eds) *Word recognition in beginning literacy*. London: Lawrence Erlbaum, 89–120.
- Montgomery J, Magimairaj B, and Finney M (2010) Working memory and specific language impairment: An update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology* 19: 78–94.

- Neilson R (2003a) *Sutherland Phonological Awareness Test: Revised*. Jamberoo: Language Speech and Literacy Services.
- Neilson R (2003b) *Astronaut invented spelling test*. Jamberoo: Weston Print.
- Pennington B (2006) From single to multiple deficit models of developmental disorders. *Cognition* 101: 385–413.
- Pennington B and Bishop D (2009) Relations among speech, language and reading disorders. *Annual Review of Psychology* 60: 283–306.
- Rees R (2001) Principles of psycholinguistic intervention. In: Stackhouse J and Wells B (2001) *Children's speech and literacy difficulties: Identification and intervention*. London: Whurr, 66–95.
- Roy P and Chiat S (2008) Beyond outcomes: The importance of developmental pathways. In: Joffe V, Cruice M, and Chiat S (eds) *Language disorders in children and adults: New issues in research and practice*. Chichester: Wiley-Blackwell, 1–19.
- Rvachew S, Nowak M, and Cloutier G (2004) Effect of phonemic perception training on the speech production and phonological awareness skills of children with expressive phonological delay. *American Journal of Speech-Language Pathology* 13: 250–63.
- Semel EM, Wiig EH, and Secord WA (2003) *Clinical evaluation of language fundamentals*. 4th edition. San Antonio, TX: The Psychological Corporation.
- Semel EM, Wiig EH, and Secord WA (2006) *Clinical evaluation of language fundamentals*. 4th Australian standardized edition. Marickville, New South Wales: Harcourt Assessment.
- Snowling M and Hulme C (1994) The development of phonological skills. *Philosophical Transactions of the Royal Society B* 346: 21–27.
- Stackhouse J, Vance M, Pascoe M, and Wells B (2007) *Compendium of auditory and speech tasks: Children's speech and literacy difficulties*. Chichester: John Wiley.
- Stackhouse J and Wells B (1997) *Children's speech and literacy difficulties: A psycholinguistic framework*. London: Whurr.
- Sutherland D and Gillon G (2005) Assessment of phonological representations in children with speech impairment. *Language Speech and Hearing Services in Schools* 36: 294–310.
- Wechsler D (1991) *Wechsler Intelligence Scale for Children: Third Revision*. New York: The Psychological Corporation.
- Wechsler D (2004) *Wechsler Preschool and Primary Scale of Intelligence: Third edition*. Cleveland: Psychological Corporation.

Appendix I Items from the quality of phonological representations task

Item	Phonological representation
Training A: Boomerang	/bʊmərəɪŋ/
Training B: Ambulance	/æmbjuləns/
1. Helicopter	/helikɔptɹ/
2. Telescope	/teləskəʊp/
3. Dominoes	/dɒmɪnoʊz/
4. Crocodile	/krɒkədaɪl/
5. Television	/teləvɪʒən/
6. Hippopotamus	/hɪpəpɒtəməs/
7. Binoculars	/baɪnɒkjuləz/
8. Microphone	/maɪkrəfəʊn/
9. Rhinoceros	/raɪnɒsərəs/
10. Spaghetti	/spəʒeti/

Paper 4: Claessen, M., Leitão, S., Kane, R. & Williams, C. (in press) Phonological processing skills in Specific Language Impairment. *International Journal of Speech-Language Pathology*.

Phonological processing skills in specific language impairment

MARY CLAESSEN, SUZE LEITÃO, ROBERT KANE & CORI WILLIAMS

Curtin University, Curtin Health Innovation Research Institute, Perth, Australia

Abstract

In order to provide effective intervention for children with specific language impairment (SLI), it is crucial that there is an understanding of the underlying deficit in SLI. This study utilized a battery of phonological processing tasks to compare the phonological processing skills of children with SLI to typically-developing peers matched for age or language. The children with SLI had significantly poorer performance than age-matched peers on measures of phonological representations, phonological awareness, rapid automatized naming, phonological short-term memory, and one measure of working memory. Of particular significance, the SLI group also demonstrated significantly weaker performance than language-matched peers on one measure of phonological representations, and one measure of working memory. The findings provide some support for a phonological processing account of SLI and highlight the utility of using tasks that draw on a comprehensive model of speech processing to profile and consider children's phonological processing skills in detail.

Keywords: *Phonological processing, phonological representations, specific language impairment (SLI), assessment.*

Introduction

Specific Language Impairment (SLI) is a term used to describe a group of children who show a significant impairment in language ability in the absence of neurological, sensory, or physical impairment (Leonard, 1998). There is much debate in the literature about the cause, presentation, diagnosis, and treatment of SLI. Research has been hampered by the heterogeneity evident within the diagnostic group as well as a paucity of tasks to measure specific skills. This is particularly so in the area of quality of stored phonological representations, which has been identified as a potential deficit in SLI (Edwards & Lahey, 1998).

In order to provide effective and efficient interventions for children with SLI it is crucial that we have an understanding of the underlying deficit in SLI. A number of theories have been proposed. Processing theories have become prominent in recent years, specifically those which suggest that weaknesses in phonological processing may explain the profile of language difficulties observed in SLI, although researchers differ on their views of the underlying mechanism (Schwartz, 2009). Further, many researchers have proposed a substantial overlap between children with SLI and those with a diagnosis of reading disability or dyslexia (Catts, Adlof, Hogan, & Ellis Weismer, 2005; McArthur,

Hogben, Edwards, Heath, & Mengler, 2000), similarly placing an emphasis on the notion of underlying phonological processing difficulties (Gillon, 2004).

The importance of phonological processing in language acquisition underpins the mapping theory of SLI (Chiat, 2001). Mapping theory proposes that, in order to learn language, children must segment the speech stream they hear into individual words and morphemes, and, with the support of context, attach meaning (or “map”) to these segments (Chiat, 2001). There is evidence that, from a young age, infants are able to identify crucial features of speech, which aids segmentation of the incoming speech stream (Chiat, 2001). While the child uses prosodic cues to distinguish word boundaries they must then use context to make a connection between the sounds they hear and the referent. Chiat (2000) notes that children as young as 9 months are able to point to a familiar item when named, indicating that, even prior to the emergence of single words, children are able to map between phonology and semantics. For concrete words, such as nouns, segmenting the speech stream and isolating individual words is facilitated by adults' use of strategies such as decreased rate of speech, and a focus on talking about the here and now. The task is much more difficult for abstract words such as verbs, as their referent is only fleeting. Chiat

(2001) proposed that the widespread impairment in language observed in children with SLI may be explained by impaired phonological processing skills which disrupt this mapping of phonological form onto meaning.

Phonological memory plays a vital role in the segmentation of the incoming speech stream and subsequent development of precise and accurate phonological representations in the lexicon as words are learned. Gathercole and Baddeley (1990) suggested that the deficits seen in SLI can be explained by limited phonological memory capacity. This limitation may result in reduced quantity and/or quality of information stored in the lexicon, which in turn may affect the development of language more broadly.

Phonological processing

A phonological processing account of SLI suggests that a weakness in the ability to process sound-based information is, thus, at the core of SLI (Schwartz, 2009). Wagner and Torgesen (1987) suggested that this broad construct of phonological processing consists of three separate but linked phonological abilities: phonological awareness, phonetic coding in working memory, and phonological recoding in lexical access (Wagner & Torgesen, 1987).

Phonological awareness (PA) is “the awareness of the sound structure, or phonological structure, of a spoken word” (Gillon, 2004, p. 2). Phonological awareness skills are said to develop along a continuum from syllable level, to onset-rime level, and finally to phoneme level. PA can be assessed using a range of tasks such as blending or segmenting the syllables or sounds in words, and manipulating the sounds in words to form new words and performance on PA tasks is highly correlated with literacy skills (Gillon, 2004).

Phonetic coding in working memory has commonly been assessed using measures of the phonological loop and central executive, such as digits forward, digits backward, and non-word repetition. In addition, some researchers have assessed working memory capacity using competing language processing tasks. Many studies demonstrate that children with SLI have difficulty with non-word repetition (Archibald & Gathercole, 2006; Botting & Conti-Ramsden, 2001; Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones, 2000; Marton & Schwartz, 2003), and it has been suggested that difficulty in repeating non-words may be a good phenotypical marker for SLI (Bishop, North, & Donlan, 1996; Conti-Ramsden, Botting, & Faragher, 2001). Marshall and van der Lely (2009) investigated the effect of word stress and consonant clusters on the performance of children with SLI, SLI + dyslexia, dyslexia only, and typically-developing children on a non-word repetition task. They found that both

SLI and dyslexic participants performed significantly worse than even younger typically-developing participants. Of significance in this study was the finding that consonant clusters in medial position were of particular difficulty for both these groups, which suggests that non-word repetition tasks are not simply a measure of phonological working memory, but that they also draw on the storage of, and access to, phonological representations.

Rapid automatized naming is considered to be a measure of phonological processing as it measures the rapid retrieval of phonological codes from the lexicon. Rapid automatized naming tasks require a speaker to look at an array of colours, letters, digits, or objects, and name each one as quickly as possible. It has been suggested that slow performance may result from imprecise underlying phonological representations which affect accessibility (Snowling, 2000): however, difficulties at a motoric level may also have an impact. Performance on a rapid automatized naming task may, therefore, be affected by speech output as well as more generally by slow access and processing speed (Wolf & Bowers, 1999).

The range of tasks described above has been commonly used to assess the three broad areas described by Wagner and Torgesen (1987). However, a consideration of the processing demands of these tasks reveals that they draw on input and output processing skills, and require access to lexical representations, to varying degrees.

A speech processing model

In order to facilitate a clearer understanding of how phonological information is processed, encoded, stored, retrieved, and used, a psycholinguistic approach can be adopted to explore the processing demands of such tasks. The Speech Processing model developed by Stackhouse and Wells (1997) (see Figure 1) is one such example. Application of the model allows clinicians and researchers to profile and identify strengths and weaknesses in a child’s speech processing skills, and subsequently plan targeted intervention.

Input. When verbal information is received it is processed and held in working memory while phonological representations are either accessed or developed (Stackhouse & Wells, 1997; Sutherland & Gillon, 2005). Baddeley and Hitch (as cited in Gathercole & Baddeley, 1990) propose a model of memory consisting of a central executive, which oversees the allocation of attentional resources, and two modality-specific buffer systems—the visuospatial sketchpad and the phonological loop. The phonological loop is responsible for the temporary storage of verbal information, particularly novel phonological input, while other cognitive tasks such as verbal reasoning or auditory comprehension take place, and is often referred to as phonological short-term memory

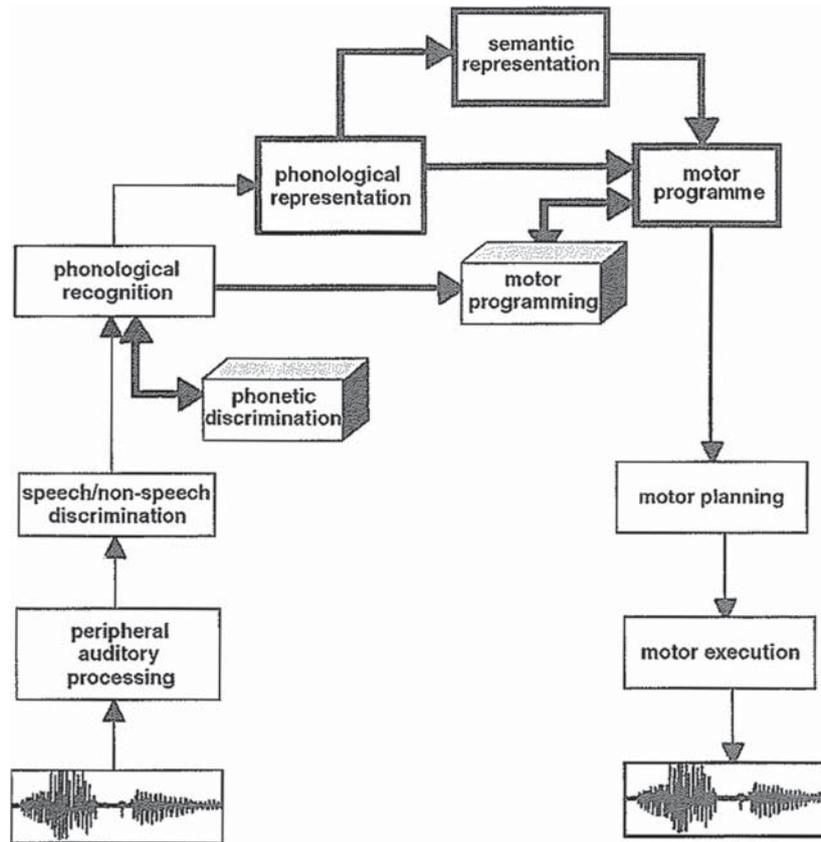


Figure 1. The speech processing profile. Children's speech and literacy difficulties: A psycholinguistic framework. Stackhouse, J. & Wells, B. (1997). Copyright John Wiley & Sons Limited. Reproduced with permission.

(Montgomery, Magimairaj, & Finney, 2010). It is widely believed that the phonological loop plays an important role in the development and storage of phonological representations in the lexicon (Montgomery et al., 2010). The central executive is considered to play an important role in the "co-ordination of the flow of information throughout working memory" (Montgomery et al., 2010, p. 79). The central executive and phonological loop must work together to ensure that incoming information can be held in short-term memory while phonological representations are developed or accessed. The episodic buffer was later added to this model (Baddeley, 2000), and is believed to function as a temporary storage device important in processing chunks of language. These processes result in long-term storage.

Storage (lexical representations). The store, or lexical representation, contains information about the meaning of a word (semantic representation), the grammar of a word (grammatical representation), a set of instructions for producing a word (motor programme), and information about how to read and write a word (orthographic representations), as well as a phonological representation (information about the sound of a word) (Stackhouse & Wells, 1997).

The concept of a phonological representation is an abstract one; however, the term has been widely used to explain the storage of phonological information in

long-term memory (Sutherland & Gillon, 2005). It is believed that there is a phonological representation or sound-based code for each word in the lexicon (Gillon, 2002). Phonological representations must contain enough information to distinguish a word from similar sounding words (Stackhouse & Wells, 1997) but be abstract enough to allow for variation in pronunciation, intonation, as well as linguistic context (Marshall, Ramus, & van der Lely, 2010). It has been proposed that low quality, poorly specified phonological representations may affect many other aspects of language (Chiat, 2001; Joanisse & Seidenberg, 1998). For example, within the mapping theory, Chiat (2001) suggests that development in the areas of vocabulary and syntax relies heavily on phonological information being perceived and represented accurately, and that phonological representations which are poorly specified and imprecise may be the result of the phonological processing weaknesses evident in SLI. Imprecise phonological representations may in turn lead to weakness in phonological awareness, and difficulties in reading and spelling (Gillon, 2004).

Output. In order to say a word the stored semantic representation must be activated and retrieved from the lexicon and then the motor program retrieved. In the case of new words or non-words (which thus can't be retrieved from the lexicon), a new motor program is constructed by selecting

stored phonological units and assembling them in new combinations. Once the motor program has been either retrieved or constructed, the various gestural targets must be assembled in real time, taking account of contextual requirements such as rhythm and intonation, as the word is said aloud (Stackhouse & Wells, 1997).

Assessing speech processing skills

Stackhouse and Wells (1997) provide a profile based on the speech processing model (see Figure 2) useful in considering the processing demands of a variety of tasks, thus allowing analysis of whether the task requires input processing, access to representations, output processing, or a combination of these.

Picture naming tasks require a child to access his/her stored semantic representation of a word and then activate his/her motor program to produce the word. Picture naming tasks are said to address the question at Level G on the speech processing profile: “Can the child access accurate motor programmes?”

(Stackhouse & Wells, 1997). Confrontation naming tasks may include a range of lexical items or draw on representations of over-learned items under speeded conditions such as in rapid automatized naming tasks. Performance on picture naming tasks is, therefore, considered to draw upon underlying phonological representations and output motor programs.

Non-word repetition tasks address the question at Level J on the speech processing profile: “Can the child articulate speech without reference to lexical representations?” Although these tasks require verbal output they do not require the child to access stored phonological representations, as the task requires online creation of a new motor program after hearing a non-word said to them, which they then have to hold in working memory while creating a new motor program. However, there is some evidence that performance is influenced by underlying knowledge of the sound structure of words (Marshall & van der Lely, 2009). Difficulties with non-word repetition may, therefore, be explained by poor input processing, weak phonological short-term memory, and

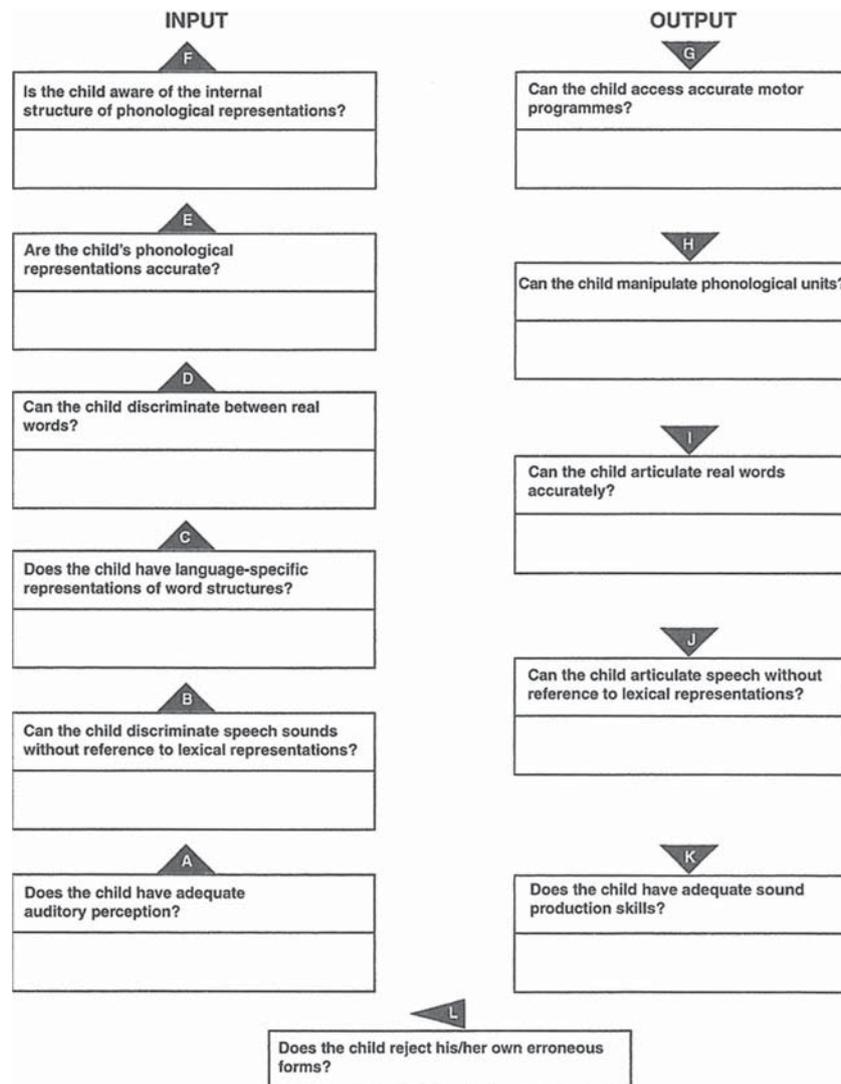


Figure 2. The speech processing profile. Children’s speech and literacy difficulties: A psycholinguistic framework. Stackhouse, J. & Wells, B. (1997). Copyright John Wiley & Sons Limited. Reproduced with permission.

difficulties with motor programming and/or motoric output (Gallon, Harris, & van der Lely, 2007). Repetition of digits forward, a measure of memory span, relies on a similar processing pathway and, therefore, can be considered to address the Level J assessment question, as access to stored representations is not mandatory. Repetition of digits in reverse order, which is considered a measure of central executive, again relies on input processing, memory, and motoric output, drawing more heavily on working memory.

Phonological awareness tasks may draw on differing processing demands depending on presentation of the task and the request made of the child. Many tasks, such as phoneme segmentation or deletion of sounds in words, are presented verbally to a child by the tester, and address the question at Level H: "Can the child manipulate phonological units?" These tasks require input processing and analysis of the heard word, then manipulation and creation of a new motor programme prior to a spoken response. Difficulties with phonological awareness may therefore reflect breakdowns at multiple levels of the speech processing pathway, in addition to the possible impact of working memory difficulties which may affect task performance.

When we turn to tasks that assess the stored phonological representations themselves, we need to be able to look in more detail at the way phonological information is represented in the lexicon. Elbro (1998, p. 149) suggested that "the distinctness of phonological representations influences the speed and accuracy of different phonological processes". Low quality, imprecise, or fuzzy phonological representations may result in imprecise productions of words, and later difficulties with literacy acquisition (Elbro, Borstrom, & Petersen, 1998; Griffiths & Snowling, 2001; Swan & Goswami, 1997).

Assessment of phonological representations

Assessment of phonological representations has been attempted using a number of different approaches. Gating tasks, for example, have been used with groups of children with SLI and typically-developing peers. Dollaghan (1998) found that children with SLI required a longer auditory segment than their peers to identify newly learned words, but not familiar words. In contrast, Mainela-Arnold, Evans, and Coady (2008) found no significant difference between groups of children with SLI and age-matched peers. Further inspection of their data led the authors to propose that, while there was no evidence for the children with SLI having more holistic phonological representations than their peers, the discrepancy between results may be explained by the age of subjects as well as word frequency measures of the items, as Mainela-Arnold et al. (2008) included older participants and used higher frequency items than Dollaghan (1998).

Many of the tasks used to assess phonological representations, such as gating or picture naming, require verbal output. However, a thorough battery of assessment tasks should also include those which do not require a spoken response. In order to address this need researchers have focused on auditory lexical decision tasks where children are required to listen to a word and determine if it is being said accurately. Tasks such as this address the question at Level E on the Stackhouse and Wells (1997) framework: "Are the child's phonological representations accurate?", and have been developed to approach the question in slightly different ways.

Crosbie, Howard, and Dodd (2004) report on a study where children with a mean age of 8;11 heard a series of real words, non-words which complied with the phonotactic constraints of English, and non-words which violated these phonotactic constraints. Children were required to judge whether the word they heard was a real word or a non-word. All participants were more accurate at identifying illegal non-words than either legal non-words or real words. The children with SLI performed significantly more poorly than typically-developing children matched for age in terms of accuracy, but not for reaction time, indicating weaknesses in the accuracy of the underlying phonological representations.

Claessen, Leitão, Heath, Fletcher, and Hogben (2009) developed a receptive measure of the accuracy of stored phonological representations. The Quality of Phonological Representations task uses a computer and the child is required to look at a familiar picture, hear the name being produced either accurately or inaccurately, and make a judgement about the accuracy of the word production. The stimulus items in this task are all multi-syllabic words which are familiar to young children. Inaccurate productions of the words were devised by altering the place, manner, or voicing of one consonant in the word, or altering the height, length, or backness of one vowel. Children indicate their response using a computer mouse, thus eliminating the verbal component of the task and providing information about the accuracy of the stored phonological representation. In a large study of two cohorts of mainstream children aged 5 and 7 years, the younger children were able to correctly reject inaccurate productions on average 87.5% of the time, while by year 2 accuracy rose to 93.8%, reflecting the developmental nature of underlying phonological representations.

In a recent study, Marshall et al. (2010) further explored the nature of underlying representations by measuring the degree of tolerance that the participants would show for modified word forms, and the degree to which this tolerance depends on the phonological context of the word. The authors reported on the performance of children with SLI, dyslexia, and SLI and dyslexia on a task in which children

were required to respond to words that contained occurrences of assimilation that were either viable (for example, brow[m] bell) or unviable (for example, brow[m] lamp), by reporting whether the target word (*brown*, as in brown roof) was unchanged. Results suggested that, while the children with dyslexia did not differ from the controls matched for age, in contrast both groups of participants with SLI did not perform at age-appropriate levels, and were more limited in their ability to accurately identify the words. Detailed analysis of the results demonstrated that the performance of the participants with SLI was explained by their “more liberal acceptance of alternative forms of words” (p. 8) rather than their ability to compensate for assimilation (Marshall et al., 2010).

While the above tasks examine a child’s underlying phonological representation at the whole word level, the Silent Deletion of Phonemes task was developed to explore a child’s ability to reflect on the structure of the stored representation (Claessen, Leitão, & Barrett, 2010). The Silent Deletion Of Phonological Representations addresses Level F on the Stackhouse and Wells (1997) framework: “Is the child aware of the internal structure of phonological representations?” In this task children are required to look at a familiar picture, but not name it. They are then asked to delete a segment of the word. For example a picture of a *beak* is provided and the child is asked, “what word would it make if I took away the /k/?” In this example the child is being asked to delete the phoneme /k/. The child then sees an array of four pictures—the correct response (bee), a semantic foil (bird), and two phonological foils (E and key), and must indicate their response using a computer mouse. Performance on the Silent Deletion Of Phonological Representations for typically-developing children in year 2 (aged 7 years) has been found to be normally distributed, with the scores above a basal level, but not approaching ceiling, again reflecting the developmental nature of phonological representations (Claessen et al., 2010).

Phonological processing in children with SLI

Over recent years, a small body of research has emerged where receptive tasks, which attempt to minimize output processing demands, have been used to measure the accuracy of phonological representations in typically-developing and language impaired children. This research has generally found that phonological representations become more refined with age and that children with SLI demonstrate lower quality phonological representations than typically-developing children. However, there are few studies where a broad range of phonological processing measures have been administered to both SLI and typically-developing participants matched for age and language and, thus, our knowledge of phonological processing skills in

SLI remains limited. A clearer picture of the phonological processing profile of this population would inform our understanding of the underlying deficit and, hence, support our ability to provide more effective intervention.

Catts et al. (2005), for example, used only measures of phonological memory and phonological awareness in their study comparing children with SLI to children with dyslexia and typically-developing peers. In contrast, in their study of phonological representations, Anthony, Williams, Aghara, Dunkelberger, Novak, and Mukherjee (2010) employed a broad range of measures designed to assess speech perception, accuracy of phonological representations, and access to stored representations, but these were only administered to typically-developing pre-primary children. An auditory lexical decision task and a task where children were required to correct inaccurate productions were utilized as measures of accuracy of phonological representations. While this research provided an excellent comparison of the nature of a range of phonological processing measures it did not include a group of SLI children. We, therefore, proposed to extend this body of work and explore the nature of phonological processing skills, using a broad range of tasks, in children with SLI and a matched groups.

In order to learn more about the nature and underlying deficit in SLI it is crucial that stringent participant selection criteria be adopted when including SLI participants in research. Our study used the DSM-IV (American Psychiatric Association, 1994) criteria for SLI in participant selection. Many other studies have used a broader definition of SLI which may result in a heterogeneous set of participants across the literature and, therefore, explain inconsistency in the research. For example, selection criteria for SLI children in some studies are based on placement at a special language unit (Conti-Ramsden, Botting, Simkin, & Knox, 2001; Conti-Ramsden, Crutchley, & Botting, 1997); however, as reported by Gathercole (2006), many of the children in these units did not meet the DSM-IV criteria for SLI. Use of stringent selection criteria for SLI is, thus, fundamental in advancing our knowledge of the nature, underlying deficits, and outcomes of SLI.

Aim of the study

The aim of this study was to draw on a range of theory-driven clinical and research assessment tasks to explore the phonological processing profiles of a well-defined group of children with SLI compared to typically-developing children matched for age, gender, and year of schooling, as well as a group of younger children matched for receptive language skills. We aimed to include in our battery, not only commonly used measures of rapid naming, short-term and working memory, and phonological awareness, but also

tasks specifically designed to assess the quality of underlying phonological representations.

It was hypothesized that the profile of processing strengths and weaknesses would be different for children with SLI, typically-developing children matched for age, and typically-developing children matched for language.

Method

Participants

A total of 63 participants were recruited for this study: 21 children with SLI, 21 typically-developing children matched for age, and 21 younger typically-developing children matched for receptive language ability. Children with SLI were recruited from a Language Development Centre in Perth, Western Australia, and typically-developing children were recruited from a metropolitan primary school.

All participants demonstrated intelligible speech, as judged by the chief researcher, an experienced speech-language pathologist; passed a hearing screen at 25 dB across the range 500–8000 Hz; and demonstrated age-appropriate pragmatic skills as judged by their classroom teacher. Parents reported that English was the first language for all participants.

All participants from the SLI group were attending a Language Development Centre where the focus is on small group teaching, with an emphasis on language and literacy education within the standard curriculum. Two speech-language pathologists are employed at the Language Development Centre and all children attending this centre receive a specific language program targeted to their individual needs.

The average age of children with SLI was 7;7 (range 6;10–8;0). The group consisted of 12 male and nine female participants. Although placement at a Language Development Centre is based on a range of test results, further testing was undertaken as part of this research to ensure all participants met the DSM-IV (American Psychiatric Association, 1994) criteria for SLI. The reference measure for language skills selected for this study was the Clinical Evaluation of Language Functioning-IV (CELF-IV) (Semel, Wiig, & Secord, 2003a) as it has sensitivity and specificity of .83 and .90, respectively, for the Core Language Score with the adopted cut-off of 1 SD below the mean (Semel, Wiig, & Secord, 2003b). All participants with SLI were required to have a Core Language Standard Score of 85 or less on the CELF-IV (Semel et al., 2003a) (see Table I). Participants were also required to have non-verbal cognitive skills within the average range as measured by the Block Design and Picture Concepts sub-tests of the Wechsler Intelligence Scale for Children-Third Revision (WISC-3) (Wechsler, 1991).

The age-matched group was made up of typically-developing children matched to SLI participants for gender, year of schooling, and age. The average age

of the age-matched participants was 7;6 (range 6;10–8;3). The age of each age-matched participant was matched, within 3 months, to the age of a child with SLI. All participants in the age-matched group were required to have a Core Language Standard Score of more than 85 on the CELF-IV (Semel et al., 2003a) and non-verbal cognitive skills within the average range as measured by the Block Design and Picture Concepts sub-tests of the WISC-3 (Wechsler, 1991).

The language-matched group consisted of typically-developing children matched to SLI participants for gender and raw score on the Concepts and Following Directions sub-test of the CELF-IV (Semel et al., 2003a). Language-matched participants were required to have a Core Language Standard Score of more than 85 on the CELF-IV (Semel et al., 2003a) and non-verbal cognitive skills within the average range as measured by the Block Design and Matrix Reasoning Sub-tests of the Wechsler Preschool and Primary Scale of Intelligence-Third Edition (WPPSI-III) (Wechsler, 2004).

The raw score on the Concepts and Following Directions sub-test of the CELF-IV (Semel et al., 2003a) was used as the language matching tool to provide a measure of underlying language knowledge. There was no significant difference between the SLI and the language-matched groups on this measure ($F(1, 40) = .008, p = .928$).

Table I reports participant scores on these tasks. There were no significant differences among the three groups in cognitive ability ($F(2, 60) = .938, p < .397, \eta^2 = .313$). There was, however, a significant group effect on language skills ($F(2, 60) = 78.57, p < .001$). Post-hoc comparison showed that the SLI group had significantly weaker language skills than both the language-matched and age-matched groups ($ps < .001$), but there was no significant difference between the language-matched and age-matched groups ($p = .996$). Thus, there were significant group differences in terms of language skills, but not non-verbal intelligence.

Table I. Summary of participant performance on selection tasks.

Selection task	SLI group	AM group	LM group
Age in months			
Mean	91.05	90.90	65.86
SD	3.60	4.19	3.47
Range	82–95	82–98	59–71
CELF-IV			
Mean	69.91	101.91	101.43
SD	11.34	6.95	9.32
Range	45–85	90–115	85–117
Cognitive skills			
Mean	9.81	10.43	9.86
SD	1.65	1.52	1.63
Range	8–13	8–13	8–13

SLI, specific language impairment; AM, age-matched; LM, language-matched; CELF-IV is the Core Language Score for the CELF-IV. Cognitive skills is the mean of the sub-test standard scores from the WISC-3 and WPPSI-III.

All participants were assessed between July and September. The SLI and age-matched participants were in their third year of formal schooling, while language-matched participants were in their first year. All testing was completed in a quiet, familiar environment within the child's school.

Ethical approval for this study was received from the Curtin University Human Research Ethics Committee and the Western Australia Department of Education and Training Research and Planning Unit. Both caregivers and participants provided informed consent to participate in the project, and procedures conformed to confidentiality guidelines.

Measures

Rapid automatized naming

Phonological recoding in lexical access was assessed using the Rapid Object Naming sub-test of the Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). In these tasks the participant is presented with an array of objects and must name them as quickly as possible. The Rapid Object Naming sub-test was selected as the objects depicted were familiar to each of the participant groups.

The Rapid Object Naming raw score on the Comprehensive Test of Phonological Processing has an alternate-form reliability of .79 for children aged 7, and .82 for children aged 5 (Wagner et al., 1999). The Rapid Automatized Naming measure was administered following the test guidelines, children's responses were recorded digitally on a laptop computer, and the raw score in seconds was used for analysis.

Measures of phonological short-term memory. The Number Repetition Forward sub-test of the CELF-IV (Semel et al., 2003a) was used as a measure of verbal short-term memory, specifically the phonological loop. This task consists of repeating groups of digits from random numbers. Participants are required to repeat groups of digits in the order they are presented. This sub-test has a moderate internal consistency of .75 for the Australian standardization sample.

Non-word repetition is recognized as a task which taps many levels of phonological processing. It has been included here primarily as a measure of phonological short-term memory. In this study the non-word repetition test developed by Dollaghan and Campbell (1998) was adopted. This task contains 16 non-words, which contain no English words in any syllable. This task has a high split-half reliability of .85, suggesting internal consistency. The non-word repetition task was presented and the percentage phonemes correct measure calculated following published guidelines (Dollaghan & Campbell, 1998).

Measures of working memory. The Number Repetition Backwards sub-test of the CELF-IV (Semel et al., 2003a) was used as a measure of central executive function. This task consists of groups of random

digits which students must repeat in reverse order. This sub-test has a moderate internal consistency of .78 for the Australian standardization sample.

The Competing Language Processing Task (Gaulin & Campbell, 1994) is a measure of a child's ability to simultaneously process and store incoming information. In this task the child is required to listen to a group of between one and six utterances. After each sentence the child is required to answer a question about the sentence, and after each group of sentences they are required to recall the final word of each sentence (Gaulin & Campbell, 1994). Although limited psychometric data are available for this measure, this task was included as the number of items recalled provides a useful measure of function of the central executive. Due to the processing demands of this task it was only administered to SLI and age-matched participants.

Measures of phonological awareness. The Sutherland Phonological Awareness Test-Revised (Neilson, 2003) was selected as the measure of phonological awareness as it assesses a range of phonological awareness skills including blending, deletion, and manipulation across a range of linguistic levels. Most of the tasks require input and output processing and draw on underlying representations. The Sutherland Phonological Awareness Test-Revised was developed in Australia and, therefore, test items and normative data were suitable for the participants in this study. It is also commonly used in clinical practice in Australia. There is strong internal consistency of .95 for the items in the Sutherland Phonological Awareness Test-Revised (Neilson, 2003). The raw score for this measure was used for analysis.

Measures of phonological representation. The Quality of Phonological Representations task (Claessen et al., 2009) is an auditory lexical discrimination task where children are required to judge the accuracy of production of multi-syllabic words, for example, "Is this a rhinoterous?" The Quality of Phonological Representations is a receptive task that aims to measure the quality of the underlying phonological representation. Good internal consistency of .84 has been found for the task with children of a similar age to the participants in this research, however, concurrent validity has not yet been established as the Quality of Phonological Representations task is unique (Claessen et al., 2009). The Quality of Phonological Representations was administered according to the published guidelines. The correct rejection measure, which is a measure of the number of inaccurate productions judged to be inaccurate, was used for analysis, as this measure was been found to have a closer approximation to normal in a large sample of typically-developing children (Claessen et al., 2009).

The Silent Deletion of Phonemes is a silent measure of a child's ability to access and manipulate their own stored phonological representations (Claessen et al.,

2010). The task requires children to look at a picture and perform a deletion task without either hearing the word said aloud or saying it aloud themselves. For example, the child is shown a picture of a nest and is asked "Look at this picture and think of the name of it, but don't say it out loud. Now what word would it make if I took away the 's' sound". They then see a computer screen containing an array of four items, the correct answer, two phonological distractors and one semantic distractor (in the example above: net, neck, knot, and bird). The child must indicate their response by clicking on it with the computer mouse. The Silent Deletion of Phonological Representations was selected as a measure of phonological representations as there is good internal consistency of .84 for the 35 test items (Claessen et al., 2010) and a correlation of .63 with the Sutherland Phonological Awareness Test–Revised (Neilson, 2003). The Silent Deletion of Phonological Representations and Sutherland Phonological Awareness Test–Revised differ on a number of key factors such as method of data presentation and nature of required response and, thus, this correlation was deemed to be sufficient to demonstrate concurrent validity (Claessen et al., 2010). The Silent Deletion of Phonological Representations was administered following the published guidelines using a laptop computer to record both accuracy and reaction time data.

Results

Data analysis

Descriptive statistics for performance on all tasks are summarized in Table II. In order to explore the profile of phonological processing skills across the three participant groups, raw scores were used in all analyses.

A mixed effects linear regression model was used to examine between-group differences in the dependent variables. The regression model was "mixed" in the sense that it included both random and fixed effects. There was one categorical random effect (children), and one categorical fixed effect (group: SLI, age-matched, language-matched). The regression model was implemented through SPSS's Generalised Linear Mixed Models (GLMM: SPSS Version 20). The histograms of the dependent variables showed clear departures from normality in the majority of cases. GLMM accommodated such departures by computing the parameter estimates of the covariance matrix with robust statistics.

In order to optimize the likelihood of convergence, and to facilitate interpretation, a separate GLMM analysis was run for each of the eight dependent measures (Rapid Automatized Naming, digits forwards, non-word repetition, digits backwards, Competing Language Processing Task, Sutherland Phonological Awareness Test–Revised, Quality of Phonological Representations, and Silent Deletion of Phonological Representations). Analysing each

Table II. Descriptive statistics for the specific language impairment (SLI, $n = 21$), age-matched (AM, $n = 21$), and language-matched (LM, $n = 21$) participants on each dependent variable.

Task	SLI, Mean (SD)	AM, Mean (SD)	LM, Mean (SD)
RAN	94.67 (23.8)	75.75 (14.73)	139.44 (49.5)
Digits forward	5.86 (1.2)	7.7 (1.82)	6.8 (1.11)
NWR	73.86 (13.12)	85.33 (6.29)	79.00 (14.71)
Digits back	2.81 (1.2)	3.2 (1.55)	1.67 (.97)
CLPT	15.05 (3.71)	19.52 (4.17)	n/a (n/a)
SPAT	40 (9.67)	46 (5.81)	17.86 (7.64)
QPR	38.24 (5.66)	47.52 (4.8)	44.10 (7.01)
SDOP	17.76 (5.97)	23.81 (6.05)	12.29 (4.28)

SLI, specific language impairment; AM, age-matched; LM, language-matched; RAN, Rapid Automatized Naming Objects; NW, non-word repetition; CLPT, Competing Language Processing Task; SPAT, Sutherland Phonological Awareness Test; QPR, Quality of Phonological Representations (Claessen et al., 2009); SDOP, Silent Deletion of Phonemes (Claessen et al., 2010).

dependent variable independently of the others will of course inflate the familywise error rate. In order to control the inflation, the Bonferroni correction was applied to the per-test alpha for the omnibus F-tests (corrected alpha = .05/8 = .006). No correction was applied to the post-hoc LSD tests since these were covered by the omnibus correction.

There was a significant main effect of group for each of the dependent variables. The results are reported in Table III. The source of each main effect was explored with a series of least significant difference tests comparing SLI to age-matched, age-matched to language-matched, and language-matched to SLI. The results of the least significant difference tests are reported in Table IV.

The age-matched group performed significantly better than the SLI group on the measures of: phonological recoding in lexical access (rapid automatized naming), phonological short-term memory (digits forwards and non-word repetition), phonological awareness (Sutherland Phonological Awareness Test–Revised), and the receptive measures of phonological representations (Quality of Phonological Representations and Silent Deletion of Phonological Representations). The significant main effect for Competing Language Processing Task indicates that the age-matched group also performed significantly better on the Competing Language Processing Task measure of working memory than the SLI group (see Table III). However, there were no significant difference between the age-matched and SLI groups on the digits backward measure of working memory (see Table IV).

The SLI group performed significantly better than the language-matched group on the measures of phonological recoding in lexical access (rapid automatized naming), phonological awareness (Sutherland Phonological Awareness Test–Revised), and one receptive measure of phonological representations (Silent Deletion of Phonological Representations), as well as one measure of working memory (digits

Table III. The main effect of group for each dependent variable.

DV	F	Numerator df	Denominator df	Effect size (ϵ^2)	Significance ^a
RAN	19.49	2	60	.410	.000
Digits forwards	8.59	2	60	.213	.001
NWR	7.63	2	60	.139	.001
Digits backwards	11.10	2	60	.228	.000
CLPT	14.20	1	40	.253	.001
SPAT	101.29	2	60	.721	.000
QPR	17.305	2	60	.308	.000
SDOP	27.25	2	60	.435	.000

RAN, Rapid Automatized Naming Objects; NWR, non-word repetition; CLPT, Competing Language Processing Task; SPAT, Sutherland Phonological Awareness Test; QPR, Quality of Phonological Representations (Claessen et al., 2009); SDOP, Silent Deletion of Phonemes (Claessen et al., 2010).

^aAll effects are significant at the Bonferroni adjusted alpha-level of .006.

backward). In contrast, the language-matched group performed significantly better than the SLI group on digits forward and one receptive measure of phonological representations (Quality of Phonological Representations). There was no significant between-group difference for the measure of non-word repetition (see Table IV).

The age-matched group performed significantly better than the language-matched group on the measure of phonological recoding in lexical access (rapid automatized naming), phonological awareness (Sutherland Phonological Awareness Test-Revised), digits backward measure of working memory, and one receptive measure of phonological representations (Silent Deletion of Phonological Representations). However, there were no significant differences between the age-matched and language-matched groups on phonological short-term memory (digits forwards and non-word repetition) and one receptive measure of phonological representations (Quality of Phonological Representations) (see Table IV).

Discussion

Examination of the scores on all measures of phonological processing reveals that the spread of scores

Table IV. Significance levels for the three LSD comparisons for each dependent variable.

DV	SLI vs AM	LM vs SLI	AM vs LM
RAN	.002**	.000***	.000***
Digits forwards	.000***	.018*	.069
NWR	.000***	.225	.068
Digits backwards	.321	.001**	.000***
SPAT	.007**	.000***	.000***
QPR	.000***	.003**	.063
SDOP	.001**	.001**	.000***

SLI, specific language impairment; AM, age-matched; LM, language-matched; RAN, Rapid Automatized Naming Objects; NWR, non-word repetition; CLPT, Competing Language Processing Task; SPAT, Sutherland Phonological Awareness Test; QPR, Quality of Phonological Representations (Claessen et al., 2009); SDOP, Silent Deletion of Phonemes (Claessen et al., 2010).

* $p < .05$; ** $p < .01$; *** $p < .001$.

for the group of SLI participants is generally wider than that of the age-matched and language-matched groups on most of the tasks. Thus, despite employing tight selection criteria, the phonological processing skills of children within the SLI group were still more heterogeneous than those of the typically-developing children.

As predicted, the children with SLI demonstrated a different profile of phonological processing skills to both groups of typically-developing children, supporting the value of employing a comprehensive battery of phonological processing tasks. Performance on each task will be discussed and interpreted below.

On the rapid automatized naming task, there were significant differences among the three groups. The age-matched children were able to retrieve well known words significantly faster than the SLI group, who were in turn significantly faster than the younger language-matched group. A developmental pattern was evident in the findings, suggesting that children with SLI were able to access these learned representations and motor programmes more rapidly than children matched for language, but not as rapidly as children matched for age. The names of the objects in the rapid automatized naming task are phonotactically simple. The performance of the children with SLI is suggestive of accurate underlying representations for these words; however, access was slower than for their age-matched peers. Given that rapid automatized naming is considered to be a good predictor of reading and spelling (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009), this highlights the importance of including speeded processing tasks in a battery of phonological processing tasks.

Turning to the measures of phonological short-term memory, the SLI group demonstrated significantly poorer performance on the number repetition forward task than both the age-matched and language-matched groups. The children with SLI also demonstrated significantly lower scores on the non-word repetition task than the age-matched group. On this task, their mean score of 73% phonemes correct also fell below the score of 79%

phonemes correct for the language-matched group, although this was non-significant. There was no significant difference between the scores for the age-matched and language-matched group. This pattern of results is consistent with many previous studies (Archibald & Gathercole, 2006; Botting & Conti-Ramsden, 2001; Catts et al., 2005; Ellis Weismer et al., 2000; Marton & Schwartz, 2003) which have found that children with SLI have significantly lower scores on measures of phonological short-term memory than typically-developing peers, and with the suggestion that non-word repetition performance may be a phenotypic marker of SLI (Bishop et al., 1996; Marton & Schwartz, 2003).

The non-significant difference between the SLI and language-matched groups on the non-word repetition task may be explained by the task selected for this study. The Non-word Repetition Test does not include words with consonant clusters, identified by Marshall and van der Lely (2009) to be of particular difficulty for children with SLI. The Children's Test of Non-word Repetition (Gathercole & Baddeley, 1996), which contains words of greater complexity, has been shown to differentiate children with SLI from younger language-matched peers (Archibald & Gathercole, 2006) and, thus, task selection may have impacted on the results.

The children with SLI obtained significantly lower scores on the Competing Language Processing Task than the age-matched group. The Competing Language Processing Task is considered to measure central executive functioning and requires information to be stored in short-term memory while further information is received and processed. Performance may be decreased when the demands of the task exceed the amount of available resources for storage and processing, reflecting reduced capacity. This finding is consistent with previous findings that children with SLI demonstrate difficulty with working memory tasks (Archibald & Gathercole, 2006; Marton & Schwartz, 2003) and suggests that children with SLI have more difficulty holding verbal information in a temporary store while further processing takes place. In contrast, on the number repetition backward task, there was no significant difference between the SLI group and the age-matched group; however, these groups were both significantly different to the younger language-matched group. This finding may reflect the overall task difficulty for all groups.

Overall weaker performance on these measures of phonological short term and working memory suggests that children with SLI are less able to process and retain verbal information compared to their age-matched peers, and, in some tasks, to children matched for language. This is likely to have a significant effect on their ability to map between phonology and semantics and, thus, develop accurate fine grained phonological representations during word learning (Chiat, 2001),

which will have implications for both speech and for the development of literacy.

On the phonological awareness task, there were significant differences among the three groups, with the age-matched group having the strongest performance and the language-matched group the weakest. The language-matched group had an average age of 5;6 and were in their first year of formal schooling. As a consequence, they had not received the same level of literacy instruction as the other older participants and it is, therefore, not surprising that their early literacy skills, such as phonological awareness, should be less developed. The SLI participants in the current study were attending a language development centre where there is a strong focus on teaching phonological awareness in the early grades and, therefore, we are not surprised that they are doing better than the language-matched children. However, the pattern of results indicates that, despite intervention, the children with SLI were still not performing at age-appropriate levels.

Most of the sub-tests in the Sutherland Phonological Awareness Test address the Level H question: "Can the child manipulate phonological units?" Such tasks follow a complex speech processing route, involving input and output processing, and generally require access to lexical representations and, thus, are subject to breakdown at many points. Our selection of the Sutherland Phonological Awareness Test-Revised, as a measure of phonological awareness, was based on its clinically utility in the Australian context. Future research should consider profiling the skills of children with SLI using a phonological awareness battery that has tasks specifically designed with a range of processing routes in mind such as in the preliminary work of Schaefer, Fricke, Szczerbinski, Fox-Boyer, Stackhouse, and Wells (2009).

The children with SLI obtained significantly lower scores on the measure of phonological representations, the Quality of Phonological Representations than both the age-matched and language-matched groups who were not significantly different from each other. Children with SLI were more likely to accept an inaccurate production of a multi-syllabic word as correct, suggesting that they have lower quality phonological representations than the typically-developing children, including younger children matched for language. In contrast, on the Silent Deletion of Phonological Representations, while the SLI participants were less accurate at performing a deletion task on their own stored representation than their age-matched peers, they were significantly better than the language-matched group. The Silent Deletion of Phonological Representations was designed as an input phonological deletion task, in other words to draw on the metalinguistic skill of deletion while minimizing both verbal input and speech output. On this task, a score higher than 15 indicates the ability to delete a phoneme from a consonant cluster (e.g., delete the /n/ sound from /snell/) The SLI group had a mean

score of 17.77, which reflects their ability to delete syllables and single consonants from words, and their emerging ability to delete phonemes from consonant clusters. In contrast, the mean score of 12.29 for the language-matched group suggests children of this age are not yet able to delete phonemes from consonant clusters. The pattern of results, therefore, may be seen to reflect the developmental emergence of phonological awareness (Gillon, 2004).

The emerging ability of children with SLI to silently delete phonemes from consonant clusters in monosyllabic words and select the correct picture in the visual array in the Silent Deletion of Phonological Representations task indicates that their underlying phonological representations for these words appear to be reasonably well established. In contrast, their weaker performance on the Quality of Phonological Representations task, which required them to reflect on multisyllabic words, indicates that their underlying phonological representations for these longer and more complex words appears to be less so. A further consideration in our interpretation of their performance is the different memory demands of these two tasks. We have confirmed that the SLI children have poorer short-term and working memory, and this weakness may impact on their ability to hold multisyllabic words in their memory while making the judgement and completing the Quality of Phonological Representations task. In contrast, the visual support of the pictures within the Silent Deletion of Phonological Representations task may have supported their performance through reducing the memory demands.

The results of this study provide some support for processing theories of SLI. The children with SLI demonstrated deficits in phonological short-term memory and working memory, which have been suggested to impact on “the creation of a phonological entry within the long-term phonological store” (Archibald & Gathercole, 2006, p. 687). Furthermore the weaker performance of the children with SLI on the Quality of Phonological Representations than both age-matched and language-matched children suggests that the deficits in memory may have affected the development of the phonological entries for these longer words and that the quality of the underlying representations may, therefore, be less detailed. The stronger performance of the children with SLI on the metaphonological tasks included in the Sutherland Phonological Awareness Test–Revised (which requires output) and the Silent Deletion of Phonological Representations (a receptive task), which both draw on monosyllabic words, suggests that their representation of these shorter words is fine grained enough to support phoneme level analysis, albeit not at the level of the age-matched cohort. Future research should investigate this more fully because high quality phonological representations are vital for accurate mapping of phonological forms onto meaning (Chiat, 2001).

This study has highlighted the value of drawing on a comprehensive model of speech processing such as that of Stackhouse and Wells (1997) to facilitate a more detailed analysis of children’s phonological processing skills than can be achieved using a standard clinical assessment task battery. The results for many of the individual tasks supported the findings of many previous studies. However, the use of a comprehensive battery covering a wide range of phonological processing skills with a group of children with SLI compared to both age-matched and language-matched groups allowed us to explore the different patterns of performance. The wide spread of scores and individual differences observed in the SLI participants were, thus, highlighted through the use of the speech processing model, and these differences are important considerations in goal-setting and intervention planning for children with SLI.

Acknowledgements

The authors would like to acknowledge and thank the schools who took part in this study and the children who participated so willingly in the project. We would also like to acknowledge John Hogben and Nick Barrett who provided valuable support and assistance in the early stages of this project.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper

References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Anthony, J., Williams, J., Aghara, R., Dunkelberger, M., Novak, M., & Mukherjee, A. (2010). Assessment of individual differences in phonological representation. *Reading and Writing, 23*, 969–994.
- Archibald, L., & Gathercole, S. (2006). Short term and working memory in specific language impairment. *International Journal of Language and Communication Disorders, 41*, 675–693.
- Baddeley, A. (2000). The episodic buffer: A new component of working memory. *TRENDS in Cognitive Sciences, 4*, 417–423.
- Bishop, D., McDonald, D., Bird, S., & Hayiou-Thomas, M. (2009). Children who read words accurately despite language impairment: Who are they and how do they do it? *Child Development, 80*(2), 593–606.
- Bishop, D., North, T., & Donlan, C. (1996). Nonword repetition as a behavioural marker for inherited language impairment: Evidence from a twin study. *Journal of Child Psychology and Psychiatry, 37*, 391–403.
- Botting, N., & Conti-Ramsden, G. (2001). Non-word repetition and language development in children with specific language impairment (SLI). *International Journal of Language and Communication Disorders, 36*, 421–432.
- Catts, H., Adlof, S. M., Hogan, T. P., & Ellis Weismer, S. (2005). Are specific language impairment and dyslexia distinct disorders? *Journal of Speech, Language, and Hearing Research, 48*, 1378–1396.
- Chiat, S. (2000). *Understanding children with language problems*. Cambridge: Cambridge University Press.

- Chiat, S. (2001). Mapping theories of developmental language impairment: Premises, predictions and evidence. *Language and Cognitive Processes*, 16, 113–142.
- Claessen, M., Leitão, S., Heath, S., Fletcher, J., & Hogben, J. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language and Communication Disorders*, 44, 121–144.
- Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: The Silent Deletion of Phonemes Task. *International Journal of Language and Communication Disorders*, 45, 411–423.
- Conti-Ramsden, G., Botting, N., & Faragher, B. (2001). Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 42(6), 741–748.
- Conti-Ramsden, G., Botting, N., Simkin, Z., & Knox, E. (2001). Follow-up of children attending infant language units: Outcomes at 11 years of age. *International Journal of Language and Communication Disorders*, 36, 207–219.
- Conti-Ramsden, G., Crutchley, A., & Botting, N. (1997). The extent to which psychometric tests differentiate subgroups of children with SLI. *Journal of Speech, Language, and Hearing Research*, 40, 765–777.
- Crosbie, S., Howard, D., & Dodd, B. (2004). Auditory lexical decisions in children with specific language impairment. *British Journal of Developmental Psychology*, 22, 103–121.
- Dollaghan, C. (1998). Spoken word recognition in children with specific language impairment. *Applied Psycholinguistics*, 19, 193–207.
- Dollaghan, C., & Campbell, T. F. (1998). Nonword Repetition and Child Language Impairment. *Journal of Speech, Language, and Hearing Research*, 41, 1136–1146.
- Edwards, J., & Lahey, M. (1998). Non word repetitions of children with specific language impairment: Exploration of some explanations for their inaccuracies. *Applied Psycholinguistics*, 19, 279–309.
- Elbro, C. (1998). When reading is “readn” or somthn. Distinctness of phonological representations of lexical items in normal and disabled readers. *Scandinavian Journal of Psychology*, 39, 149–153.
- Elbro, C., Borstrom, I., & Petersen, D. K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, 33, 36–60.
- Ellis Weismer, S. E., Tomblin, B., Zhang, X., Buckwalter, P., Chynoweth, J., & Jones, M. (2000). Nonword repetition performance in school-aged children with and without language impairment. *Journal of Speech, Language, and Hearing Research*, 43, 865–878.
- Gallon, N., Harris, J., & van der Lely, H. (2007). Non-word repetition: An investigation of phonological complexity in children with grammatical SLI. *Clinical Linguistics and Phonetics*, 21, 435–455.
- Gathercole, S. (2006). Complexities and constraints in nonword repetition and word learning. *Applied Psycholinguistics*, 27, 599–613.
- Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, 29, 336–360.
- Gathercole, S. E., & Baddeley, A. D. (1996). *The Children's Test of Nonword Repetition*. London: Psychological Corporation.
- Gaulin, C., & Campbell, T. F. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual and Motor Skills*, 79, 55–64.
- Gillon, G. (2002). Follow-up study investigating the benefits of phonological awareness intervention for children with spoken language impairment. *International Journal of Language, and Communication Disorders*, 37, 381–400.
- Gillon, G. (2004). *Phonological awareness: From research to practice*. New York: The Guilford Press.
- Griffiths, Y. M., & Snowling, M. S. (2001). Auditory word identification and phonological skills in dyslexic and average readers. *Applied Psycholinguistics*, 22, 419–439.
- Joanisse, M. F., & Seidenberg, M. S. (1998). Specific language impairment: A deficit in grammar or processing? *Trends in Cognitive Sciences*, 2, 240–247.
- Leonard, L. B. (1998). *Children with specific language impairment*. Massachusetts: MIT.
- Mainela-Arnold, E., Evans, J., & Coady, J. (2008). Lexical representations in children with SLI: Evidence from a frequency-manipulated gating task. *Journal of Speech, Language, and Hearing Research*, 51, 381–393.
- Marshall, C., & van der Lely, H. (2009). Effects of word position and stress on onset cluster production: Evidence from typical development, specific language impairment, and dyslexia. *Language*, 85, 39–57.
- Marshall, C., Ramus, F. and van der Lely, H. (2010). Do children with dyslexia and/or specific language impairment compensate for place assimilation? Insight into phonological grammar and representations. *Cognitive Neuropsychology*, 27, 563–586.
- Marton, K., & Schwartz, R. G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, 46, 1138–1153.
- McArthur, G. M., Hogben, J. H., Edwards, V. T., Heath, S. M., & Mengler, E. D. (2000). On the ‘specifics’ of specific reading disability and specific language impairment. *Journal of Child Psychology and Psychiatry*, 41, 869–874.
- Montgomery, J., Magimairaj, B., & Finney, M. (2010). Working memory and specific language impairment: An update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology*, 19, 78–94.
- Neilson, R. (2003). *Sutherland Phonological Awareness Test - Revised*. Jamberoo, NSW: Language Speech and Literacy Services.
- Schaefer, B., Fricke, S., Szczerbinski, M., Fox-Boyer, A., Stackhouse, J., & Wells, B. (2009). Development of a test battery for assessing phonological awareness in German-speaking children. *Clinical Linguistics and Phonetics*, 23, 404–430.
- Schwartz, R. (2009). Specific language impairment. In R. Schwartz (Ed.), *Handbook of child language disorders*. (pp. 3–43). Hove: Psychology Press.
- Semel, E., Wiig, E., & Secord, W. (2003a). *Clinical Evaluation of Language Fundamentals - IV*. Marickville: Harcourt Assessment.
- Semel, E., Wiig, E., & Secord, W. (2003b). *Clinical Evaluation of Language Fundamentals -Fourth Edition Examiner's Manual*. Marickville: Harcourt Assessment.
- Snowling, M. (2000). *Dyslexia*. Oxford: Blackwell Publishers.
- Stackhouse, J., & Wells, B. (1997). *Children's speech and literacy difficulties: A psycholinguistic framework*. London: Whurr.
- Sutherland, D., & Gillon, G. (2005). Assessment of phonological representations in children with speech impairment. *Language, Speech, and Hearing Services in Schools*, 36, 294–310.
- Swan, D., & Goswami, U. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, 66, 18–41.
- Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101, 192–212.
- Wagner, R., Torgesen, J., & Rashotte, C. (1999). *Comprehensive Test of Phonological Processing*. Austin, TX: Pro-Ed.
- Wechsler, D. (1991). *Wechsler Intelligence Scale for Children - Third Revision*. New York: The Psychological Corporation.
- Wechsler, D. (2004). *Wechsler Preschool and Primary Scale of Intelligence - Third Edition*. Cleveland, OH: Psychological Corporation.
- Wolf, M., & Bowers, P. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, 91, 415–438.

Paper 5: Claessen, M. and Leitão, S. (2012) The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14 (3) 226-234.

The relationship between stored phonological representations and speech output

MARY CLAESSEN & SUZE LEITÃO

Curtin University of Technology, Perth, Australia, and Curtin Health Innovation Research Institute, Perth, Australia

Abstract

Low quality, imprecise phonological representations have been hypothesized as an underlying deficit in Specific Language Impairment (SLI). This research compared performance on a silent judgement task and a multisyllabic word naming task using the same 10 words, for 21 children with SLI (mean age 7;6), 21 age-matched (AM) (mean age 7;6) and 21 language-matched (LM) (mean age 5;6) peers. The children with SLI demonstrated significantly poorer performance on the judgement task than either AM or LM peers, while performance on the naming task followed a developmental sequence. There was no correlation between the ability to correctly reject inaccurate productions and the ability to correctly name the items. These results support the suggestion of separate input and output phonological representations and that speech output errors should not necessarily be interpreted as indicative of underlying weakness in phonological representations. The research also highlights the value of individually-designed tasks to measure the input phonological representations for specific words.

Keywords: *Phonological processing, phonological representations, judgement, naming, assessment*

Introduction

For every word in a person's vocabulary there is a stored representation in the lexicon. This representation is believed to consist of semantic, grammatical, orthographic, and phonological information. Phonological, or sound-based, representations of words must be well enough defined to allow a child to match previously encoded sound patterns with new instances of the same sound in conversations, and thus allow for the acoustic variability that occurs both within and between speakers of the same language. The representation of the sounds in words must be formed on a very brief exposure, a process which is often referred to as fast mapping (Fisher, Hunt, Chambers, & Church, 2001).

According to holistic theories, early phonological representations are believed to contain only enough information to distinguish a word from another, and become more specified and segmented as vocabulary increases (Walley, 1993). This process, known as lexical restructuring, continues until the early school years when children refine their representations to a phoneme level (Carroll, Snowling, Hulme, & Stevenson, 2003; Maillart, Schelstraete, & Hupet, 2004). There is some evidence that young children can in fact distinguish similar sounding words and that their representations may be partly phonologically specified, although

it should be noted that the tasks used in these studies adopted a preferential looking paradigm using single syllable words (Mani & Plunkett, 2007; White & Morgan, 2008).

A psycholinguistic approach to assessment allows clinicians to examine the underlying processing skills required to complete assessment tasks and to then plan targeted intervention (Baker, Croot, McLeod, & Paul, 2001). Psycholinguistic models of speech processing vary in the assumptions made about phonological representations. Some models make no distinction between phonological representations accessed for input tasks such as speech perception and judgement tasks, and those accessed for output tasks such as naming (Griffiths & Snowling, 2001). Other theoretical models propose distinct but linked phonological representations for speech input and output (for example Monsell, 1987). Similarly, Stackhouse and Wells (1997) posit a phonological representation for input, and a linked motor plan for output.

Regardless of underlying beliefs, most theorists are in agreement about the importance of phonological representations in word learning and the need for accurate, segmented phonological representations to support the acquisition of literacy. Learning new words involves processing the sound-based information they

contain and establishing an underlying phonological representation associated with its meaning. The phonological representations hypothesis of dyslexia suggests that individuals with dyslexia have difficulty establishing precise and well-formed phonological representations and that this impacts on their ability to learn to read and spell (Griffiths & Snowling, 2001; Swan & Goswami, 1997). At the early stages of literacy acquisition, children are required to map between an orthographic representation and a phonological representation, and this will be compromised if the phonological representation is low in quality.

Phonological representations in SLI

Specific Language Impairment (SLI) is a term used to describe a group of children who show a significant impairment in language ability in the absence of neurological, sensory, or physical impairment (Leonard, 1998). Children with SLI have difficulty establishing and maintaining well specified, accurate phonological representations (Pennington & Bishop, 2009). There is also evidence that children with SLI show significantly more difficulty learning new words than typically-developing peers (Kan & Windsor, 2010). Both Gathercole and Baddeley (1990) and Edwards and Lahey (1998) found that children with SLI demonstrated poorer non-word repetition skills as compared to their peers. Gathercole and Baddeley (1990) attributed this to difficulty storing phonological information in memory; however, Edwards and Lahey (1998) hypothesized that this was a result of their phonological representations rather than purely a difficulty with phonological memory. Specifically it was proposed that children with SLI have phonological representations which are more holistic and less segmental than typically-developing children of the same age (Edwards & Lahey, 1998).

Maillart et al. (2004) compared French-speaking children with SLI with typically-developing children matched for receptive vocabulary on a multisyllabic word judgement task. In this task children were required to judge whether words spoken by the examiner were real words or not. Maillart et al. found that ability to complete this task was correlated with vocabulary for both SLI and TD participants, but that children with SLI had particular difficulty rejecting pseudowords that closely resembled real words, suggesting that their phonological representations were less well specified than those of typically-developing children. Given these findings, it is essential that tasks to measure phonological representations are included in a comprehensive assessment battery in order to explore underlying deficits, and plan effective intervention.

Tasks to measure phonological representations

A range of tasks are reported in the literature which purport to measure existing underlying phonological representations, however they have different processing routes. Some tasks contain an output or motoric component, while others are purely input tasks; however all require the child to draw on the underlying stored semantic representation.

The gating paradigm (Grosjean, 1980) involves identifying a word from increasingly longer auditory segments of the word. Gating tasks have been used to study lexical access in children (Dollaghan, 1998; Montgomery, 1999). Both studies found that children with SLI did not differ from age-matched peers in the length of acoustic segment required to identify familiar words. Dollaghan (1998) also included newly learnt words and found that children with SLI required a longer auditory segment than peers to identify these unfamiliar items, and concluded that children with SLI have more difficulty establishing phonological representations. However, inconsistent results across studies using gating tasks (Wesseling & Reitsma, 2001) has led to a decrease in their use to measure quality of phonological representations.

Baker and Munro (2011) suggest that naming tasks, particularly those containing multisyllabic words, may provide an insight into a child's stored phonological representations. In order to name a picture correctly the semantic representation must be accessed, followed by the motor program associated with the lexical representation, then the motor plan accessed and the name of the picture produced. Naming tasks have also been used to measure both storage and access of phonological representations in children with dyslexia (Elbro, 1998; Snowling, van Wagtenonk, & Stafford, 1988). Snowling et al. (1988) found that children with dyslexia were able to name fewer pictures than age-matched peers despite similar performance on a receptive vocabulary task. Naming tasks, however, draw on output processing in addition to the stored phonological representation.

In recent years there has been a focus on developing silent measures of phonological representations (Maillart et al., 2004; Sutherland & Gillon 2005) in order to eliminate the spoken or output component of the task and thus obtain a more pure measure of stored phonological representations. Such tasks involve the child hearing the word spoken aloud, and then accessing their stored semantic and phonological representation in order to match the heard word with their stored representation of the word and make some sort of decision or judgement about the accuracy of the production they heard.

The Quality of Phonological Representations task (Claessen, Heath, Fletcher, Hogben, & Leitão, 2009) is a computer-based task which was developed in order to provide a silent measure of phonological representations. In this task children are

presented with accurate and inaccurate productions of a multisyllabic word and asked to indicate which productions are accurate and which are not (Claessen et al., 2009). The child hears a word produced and must access their stored semantic representation and phonological representation in order to match the heard word with their stored phonological representation of the word. As a computer mouse is used to indicate a response, there is no output processing required. This task was found to provide a valid and reliable measure of the quality of stored phonological representations. Children with SLI have been found to perform significantly worse on this task than typically-developing children, matched for age, and younger, typically-developing children matched for receptive language skills (Claessen & Leitão, in press). This finding supports the hypothesis that children with SLI have difficulty developing well-specified accurate phonological representations.

This paper will explore the relationship between performance on input and output speech processing tasks, designed to assess stored phonological representations in children with SLI, typically-developing children matched for age, and typically-developing children matched for receptive language skills. If a single representation is accessed for both input and output, performance on both measures of phonological representation should be equal. If, however, two distinct representations are accessed, performance may differ between the tasks. Furthermore, using the same lexical items for both input and output tasks would help us gain further insight into the nature of the underlying stored phonological representations. To our knowledge there are no reported tasks which include the same stimulus items for both input and output with SLI, age-matched (AM) and language-matched (LM) participants.

Hypotheses

The following hypotheses will be addressed.

- 1) Children with SLI will have decreased accuracy compared to AM children at correctly rejecting inaccurate productions of multisyllabic words. There will be no significant difference between performance of the children with SLI and the LM group.
- 2) Children with SLI will have decreased accuracy at correctly naming multisyllabic words (both phonologically and semantically) than AM children. There will be no significant difference between performance of the children with SLI and the LM group.
- 3) There will be a correlation between the ability to correctly name the items and the ability to correctly reject inaccurate productions.

Method

Approval for all aspects of this research was granted from the Curtin University Human Research Ethics Committee and the Western Australia Department of Education and Training Research and Planning Unit. Procedures complied with confidentiality guidelines and both caregivers and participants provided informed consent to participate.

Participants

Twenty-one children (12 males and nine females) with SLI were recruited as participants in this study. The average age of SLI participants was 7;6 (range 6;10–8;10). All children with SLI attended a Language Development Centre in Perth, Western Australia, and were in their third year of formal schooling. Language Development Centres are government-funded primary schools for children who have significant language impairment, in the presence of average non-verbal intelligence and no other sensory impairment. For inclusion in this study all participants with SLI were required to have non-verbal cognitive skills within the average range as measured by the Block Design and Picture Concepts sub-tests of the Wechsler Intelligence Scale for Children–Third Revision (WISC-3) (Wechsler, 1991) and a Core Language Standard Score of 85 or less on the Clinical Evaluation of Language Fundamentals–IV (CELF-IV) (Semel, Wiig, & Secord, 2003a) (see Table I). The CELF-IV was selected as the reference measure for language skills as it has sensitivity and specificity of .83 and .90, respectively, for the Core Language Score, with the adopted cut-off of 1 SD below the mean (Semel, Wiig, & Secord, 2003b). Children with SLI were required to pass a hearing screen at 25 dB across the range 500–8000 Hz; have intelligible speech; appropriate pragmatics; and English as their first language as reported by the child's teacher and managing speech-language pathologist.

Twenty-one typically-developing children matched to the SLI participants by age were recruited from a metropolitan primary school as an age-matched (AM) group. Participants in the AM group were matched to the SLI group by gender, year of schooling, and age within 3 months. The mean age of the AM group was 7;6 (range 6;10–8;3). Twenty-one typically-developing children matched to the SLI participants by gender and receptive language skills were recruited as a language-matched (LM) group. The mean age of the LM group was 5;6 with a range of 4;11–5;11. Receptive language was matched using the raw score on the Concepts and Following Directions Sub-test on the CELF-IV. All typically-developing children were required to have intelligible speech, appropriate pragmatic skills, and English as their first language as reported by their teacher. All typically-developing children were also required to

Table I. Participant characteristics.

Variable	Language group								
	SLI			AM			LM		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (months)	91.05	3.60	82–96	90.90	4.19	82–98	65.86	3.47	59–71
Cognitive skills ^a	9.81	1.65	8–13	10.43	1.62	8–13	9.86	1.63	8–13
Language skills ^b	69.90	11.34	45–85	101.19	6.95	90–115	101.43	9.32	85–117
Receptive language skills ^c	26.62	9.135	11–42	40.38	6.289	23–50	26.86	7.735	15–42

SLI, Specific Language Impairment group; AM, age-matched group; LM, language-matched group.

^aCognitive skill is the mean of the sub-test standard scores from the WISC-3, and WPPSI-III.

^bThe Language skills score is the Core Language Score obtained from the CELF-IV.

^cThe Receptive language score is the raw score from the Concepts and Following Directions sub-test of the CELF-IV.

have a Core Language Standard Score of more than 85 on the CELF-IV (Semel et al., 2003a), and non-verbal cognitive skills within the average range as measured by the Block Design and Picture Concepts sub-tests of the WISC-3 (Wechsler, 1991) for the AM group, and measured by the Block Design and Matrix Reasoning Sub-tests of the Wechsler Preschool and Primary Scale of Intelligence–Third Edition (WPPSI-III) (Wechsler, 2004) for the LM group. Participants’ performance on selection measures are summarized in Table I.

Measures

Judgement. The QPR task (Claessen et al., 2009) requires participants to judge the accuracy of production of multisyllabic words. The task consists of 10 multisyllabic words which are commonly known by children of this age. The multisyllabic words included in the task were: *binoculars, dominoes, crocodile, telescope, rhinoceros, television, hippopotamus, microphone, spaghetti, and helicopter*. These items were selected as they are highly imageable, and were known by a pilot group of children of the same age. For each multisyllabic word, there are 10 items, four correct productions and six productions where one phoneme has been changed. Consonants were varied by place, manner, or voicing, and vowels by height, length, or backness. See Table II for examples of items. The child must listen to each production and decide if it was said correctly or not. Children are informed that sometimes the word will be said correctly and that sometimes it will be said “a little bit wrong”. Two training items, with specific feedback on performance, precede the test items to ensure the child is focusing on phonological accuracy rather than semantic accuracy. Details of the task, including task construction, and reliability and validity are available (Claessen et al., 2009). In the current study,

the task was administered according to these guidelines. The correct rejection measure is a measure of the accuracy at correctly rejecting inaccurate productions of words. This measure was used for analysis as it has been found to be a valid and reliable measure (Claessen et al., 2009).

Multisyllabic word naming task. The multi-syllabic word naming task consisted of the 10 items from the QPR task. Each picture was displayed on a computer screen and the child asked to name the picture. The multisyllabic word naming task was carried out immediately following the judgement task to ensure the child was accessing his/her own stored phonological representation in the judgement task. If a shortened form (e.g., *hippo, TV*) was provided, children were prompted with “That’s the short name, can you tell me the long name?” Responses were digitally recorded.

Procedure

Each participant was assessed individually by the first author, an experienced speech pathologist in a familiar setting within their school. Participant selection measures were completed in one 45 minute session. On a different day, participants completed the QPR task and then the multisyllabic naming task.

Analysis

Judgement. For the QPR task, responses are automatically scored and recorded digitally. Following testing a record of accuracy for each multisyllabic word is automatically produced for each participant.

Multisyllabic word naming task. Each participant’s attempt to name the multisyllabic words was digitally

Table II. Examples of Quality of Phonological Representation (QPR) task items.

Stimulus item	Correct production	Inaccurate productions
rhinoceros	/ˈrɪnɒsərəs/	/ˈrɪnɒtərəs/, /ˈrɪnɒsərəs/, /ˈrɪnɒsərəz/, /ˈrɪnɒsərəs/, /ˈrɪnæsərəs/, /ˈrɪnɒsərəs/

Int J Speech Lang Pathol Downloaded from informahealthcare.com by 58.7.229.192 on 05/08/12 For personal use only.

Table III. Means, standard deviations, and ranges for Quality of Phonological Representation task (QPR), semantically and phonologically correct scores and Percentage of Consonants Correct (PCC).

Measure	Language group								
	SLI			AM			LM		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
QPR	38.24	5.66	30–47	4.80	44.10	39–56	QPR	38.24	30–57
Semantically and phonologically correct	6.90	2.91	0–10	7.52	2.11	1–10	4.38	1.66	2–7
PCC	92.14	8.49	69–100	95.48	4.08	83–100	87.33	5.39	73–96

SLI, Specific Language Impairment group; AM, age-matched group; LM, language-matched group.

recorded. Items were coded as semantically correct if the child was able to correctly identify the picture and provide the correct name for it.

Each item was later transcribed into broad phonetic transcription by the authors, both of whom are experienced with this level of transcription. Inter-rater reliability was carried out on percentage of consonants correct (PCC) (Shriberg, Austin, Lewis, McSweeney, & Wilson, 1997) for 25% of the items and was found to be 98%. Phonological accuracy was then determined by calculating how many items each child could name correctly without phonological errors (semantically and phonologically correct) followed by a more detailed analysis of percentage of consonants correct.

Results

Judgement

Descriptive statistics for each groups’ performance are reported in Table III. For the correct rejection measure, the mean of both the AM and the LM group fell within the average range for their ages (Claessen et al., 2009). However, the mean for the SLI group fell more than 1 SD below the mean for their age.

Prior to analysis the QPR data were examined and as all assumptions were met a multivariate analysis of variance (MANOVA) was used to examine the differences between the participant groups. The QPR variable was significantly different across groups, $F(2, 60) = 13.337, p < .001, \text{partial } \eta^2 = .308$. Post-hoc analysis using Tukey’s HSD ($\alpha = .05$) revealed that the SLI group ($M = 38.24, SD = 5.66$) performed significantly more poorly than either the age-matched ($M = 47.52, SD = 4.80$), or language-matched ($M = 44.10, SD = 7.01$) participants. The difference between the AM and LM groups was not significant. Effect size for these relationships were $d = 1.319, .832, \text{ and } .487$, respectively, indicating moderate-to-large effect sizes.

A detailed analysis of each groups’ ability to correctly reject the six inaccurate productions for each word is presented in Figure 1. In general, the SLI group was weaker than the LM group, who were generally weaker than the AM group for most words. The general pattern was not followed for the words *crocodile*, *dominoes*, and *television*.

Multisyllabic word naming

In order to name a picture, first the semantic representation must be accessed. On average children with

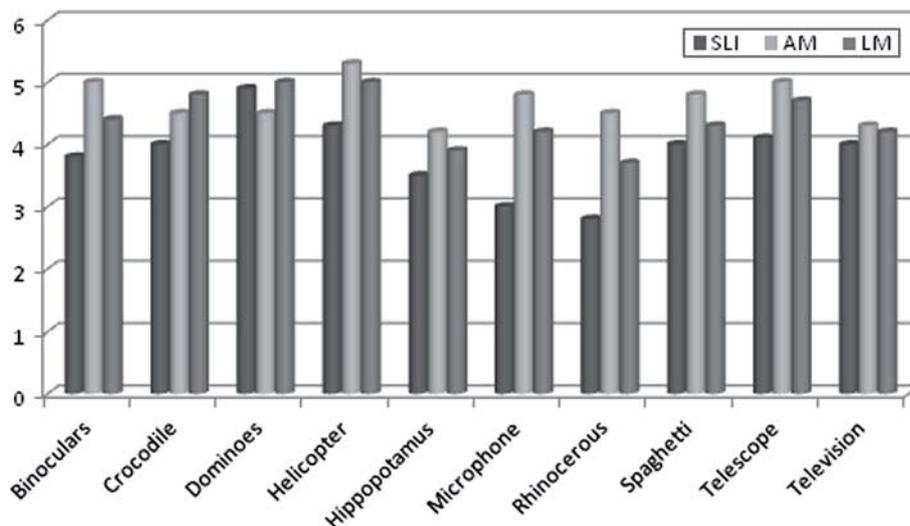


Figure 1. Correct rejections for individual words.

SLI knew 9.43 (SD = 1.36) of the words; age-matched children knew 9.52 (SD = 1.12) and language-matched children 9.19 (SD = 1.03), thus indicating most children knew the names of each item and accessed the correct semantic representation. There was no significant difference between groups.

Phonological accuracy. In order to explore phonological accuracy, a calculation was made of those responses scored as semantically and phonologically correct. Descriptive statistics for phonological accuracy for each group are presented in Table III.

Due to violations in the assumptions for conducting an ANOVA, non-parametric statistical analysis was undertaken. A Kruskal-Wallis ANOVA was conducted to explore the differences between groups on ability to produce the multisyllabic words correctly as scored semantically and phonologically correct. This test indicated a significant difference between the SLI group (Mean Rank = 37.14), the AM group (Mean Rank = 41.07), and the LM group (Mean Rank = 17.79), H (corrected for ties) = 19.759, $df = 2$, $n = 63$, $p < .001$, Cohen's $f = .684$, which is a large effect size. In order to explore where the differences lay, a series of Mann-Whitney U-tests were used. This revealed that the language-matched group had a significantly lower semantically and phonologically correct score than either the SLI group $U = 93.0$, $z = -3.234$ (corrected for ties), $p < .001$, two-tailed, or the age-matched group $U = 49.5$, $z = -4.347$ (corrected for ties), $p < .001$, two-tailed. The effects are large ($r = .407$) and large ($r = .551$), respectively. Performance on individual words was subsequently examined. There was no pattern based on either group or word length.

In order to further explore the phonological accuracy of productions for each group, analysis of PCC was conducted. Descriptive statistics for PCC for each group are presented in Table III.

Due to violations in the assumptions for conducting an ANOVA, non-parametric statistical analysis was undertaken. A Kruskal-Wallis ANOVA was conducted to explore the differences between groups on ability to produce the multisyllabic words correctly as measured by PCC. This test indicated a significant difference between the SLI group (Mean Rank = 35.24), the AM group (Mean Rank = 42.36), and the LM group (Mean Rank = 18.40), H (corrected for ties) = 19.125, $df = 2$, $n = 63$, $p < .001$, Cohen's $f = .668$, which is a large effect size. In order to explore where the differences lay, a series of Mann-Whitney U-tests were used. This revealed that the language-matched group had a significantly lower PCC than either the SLI group $U = 110.5$, $z = -2.777$ (corrected for ties), $p < .005$, two-tailed, or the age-matched group $U = 45$, $z = -4.448$ (corrected for ties), $p < .001$, two-tailed. The effects are medium ($r = .034$) and large ($r = .56$), respectively.

Table IV. Correlations between judgement and semantically and phonologically correct (S & P correct) for each group.

Measure	Language group		
	SLI S & P correct	AM S & P correct	LM S & P correct
Judgement	-.136	.169	.320
Sig (2-tailed)	.556	.465	.158

SLI, Specific Language Impairment group; AM, age-matched group; LM, language-matched group.

Correlation between naming and judgment. To assess the size and relationship between the ability to judge the accuracy of productions of words and the ability to produce them accurately, a bivariate Pearson's correlation was calculated. Correlations between the variables for each group are presented in Table IV. The correlations between the two variables were positive for both the AM and LM groups and negative for the SLI group, however no correlations were significant.

Given this lack of significance, it was decided to explore the relationship between judgement and production of each of the 10 words for each group. A Pearson's chi-square test of contingencies (with $\alpha = .05$) was carried out for each word, in order to evaluate whether judgement was related to accurate production of that word. The chi-square test was not significant.

Ability to judge own incorrect productions. Detailed analysis of the data highlighted a number of occasions where a child was asked to judge an inaccurate production (input) that directly matched their own incorrect production (output). In order to explore this further, we conducted a more detailed analysis of these instances. For example where a child named *binoculars* /bɒnɒkjʊləz/ as [bɒnɒkliəz], we investigated how they judged the accuracy of the item "Is this /bɒnɒkliəz/?". It is important to recognize that only one example of naming was analysed and therefore we have no evidence of stability of production, and as such this may not be the only way the child produces this word.

The data were examined and 31 occasions were identified where a child was presented with his/her own inaccurate production in the judgement task (see Table V). Of the six examples for children with SLI, in three cases they accepted their own inaccurate production as correct. Of the nine examples for the age-matched group, in two cases the inaccurate productions were accepted as correct, and both these occasions occurred in the one participant. For the younger, language-matched participants, there were many more examples (16). In ten of these occurrences, the language-matched children rejected their own inaccurate productions, while in the other six cases they accepted their inaccurate productions.

Table V. Judgement of own inaccurate productions.

Group	Production	Accepted/rejected
SLI	[hɪtʌ pɔtʌməs]	Rejected
	[krɔtʌdail]	Rejected
	[tɪlʌskɔp]	Accepted
	[.ɹaɪmɪtʌrəs]	Rejected
	[pəs'geti]	Accepted
	[hɪtʌ pɔtʌməs]	Accepted
AM	[bə nɔkliəz]	Rejected
	[maɪkwəfoun]	Rejected
	[dɔmɪnɔz]	Rejected
	[telʌskɔp]	Rejected
	[.ɹaɪ nɔsərəz]	Rejected
	[hɪtʌ pɔtʌməs]	Accepted
	[bəs'geti]	Accepted
	[bə nɔkliəz]	Rejected
LM	[hɪtʌ pɔtʌməs]	Rejected
	[bə nɔkliəz]	Accepted
	[maɪkwəfoun]	Rejected
	[bə nɔkliəz]	Rejected
	[bəs'geti]	Rejected
	[bəs'geti]	Accepted
	[bə nɔkliəz]	Rejected
	[hɪtʌ pɔtʌməs]	Rejected
	[bəs'geti]	Accepted
	[bəs'geti]	Accepted
	[bə nɔkliəz]	Rejected
	[hɪtʌ pɔtʌməs]	Accepted
	[hɛli'kɔbdə]	Rejected
	[hɪtʌ pɔtʌməs]	Rejected
	[bə nɔkliəz]	Rejected
[hɪtʌ pɔtʌməs]	Rejected	
[maɪkwəfoun]	Accepted	

SLI, Specific Language Impairment group; AM, age-matched group; LM, language-matched group.

Discussion

This study aimed to explore the relationship between input and output speech processing using a computer-based task designed to assess quality of phonological representations in children with SLI, and age-matched and language-matched peers. It was hypothesized that children with SLI would have decreased accuracy at both correctly rejecting inaccurate productions of multisyllabic words and naming multisyllabic words. It was also hypothesized that there would be a correlation between the ability to correctly name multisyllabic words and the ability to reject inaccurate productions. The SLI participants performed significantly worse on the judgement task, despite similar naming skills to the AM group. There was no significant correlation between judgement and naming at either a task level or for individual words for any of the participant groups.

On the input, or judgement task, the children with SLI demonstrated significantly poorer performance than either age- or language-matched peers. This

suggests, as hypothesized, that children with SLI have lower quality phonological representations than the AM or LM groups. This result is consistent with the recent findings of Marshall, Ramus, and van der Lely (2010) that children with SLI were more likely to accept productions of words with slight assimilatory variation in consonant place as correct.

On the phonological accuracy measure, the pattern of results followed a developmental sequence, with the younger language-matched group demonstrating significantly weaker performance than either of the other two groups. Thus, the hypothesis that children with SLI will have decreased accuracy at naming multisyllabic words, compared to the younger language-matched participants, was not supported.

Performance on the judgement task suggested that children with SLI had significantly weaker, more imprecise phonological representations than the typically-developing children. However, performance on the naming task (phonological accuracy measure) suggested that, for naming, differences were developmental. Both the participants with SLI and the younger typically-developing participants had some residual output difficulties as evident in their scores on the naming task.

There was no correlation between the ability to correctly reject inaccurate productions and the ability to say the words correctly. This was consistent at both the task and individual word level. As a result, there was no support for the hypothesis that a correlation would exist between the general ability to correctly reject an inaccurate production and the ability to correctly name the items.

The lack of a significant correlation between naming and judgement of the same words suggests separate input and output phonological representations. This finding is consistent with theoretical models such as Stackhouse and Wells (1997) and Monsell (1987) who propose separate but linked input and output phonological representations. This pattern supports findings such as those by Vellutino, Fletcher, Snowling, and Scanlon (2004) who reported that children with dyslexia have a marked deficit in speech production with no corresponding deficit in speech perception.

In order to further explore the relationship between stored phonological representations and correct productions, the children's ability to reject their own inaccurate productions was examined. Although the data set was small some interesting preliminary findings emerged. The children with SLI were more likely to accept their own inaccurate productions of a word as correct than the age-matched participants. For the language-matched group, there were more instances of inaccurate productions. Similarly to the SLI group, these younger participants evidenced some difficulty in rejecting their own erroneous forms, albeit at a lower rate.

Stackhouse, Vance, Pascoe, and Wells (2007, p. 74) suggest that "Accepting similar sounding non-words as the real word implies that the child's phonological

representation of that word is *fuzzy* or inaccurate". This would suggest that the children with SLI demonstrated evidence of weaker phonological representations. In contrast, in the AM group, there were nine occasions where a child was asked to judge their own inaccurate production. Only one participant accepted his own inaccurate productions as correct, and this participant did so on two occasions. This suggests the older children demonstrated evidence of more precise stored phonological representations. The LM participants appeared to fall somewhere in between.

Given that this analysis was undertaken after the data were collected there were limited opportunities for children to reject their own inaccurate productions. Further research should consider individually designing judgement tasks, using a child's own mispronunciations, in order to explore the relationship between judgement (input) and naming (output) in more detail, and further our understanding of the structure of underlying phonological representations in the lexicon.

The results of this study suggest that children with SLI have poor input *and* output phonological representations in contrast to age-matched typically-developing children, who only evidenced some residual output difficulties and performed more strongly on the judgement task. The LM children demonstrated a higher number of errors in their pronunciation of multisyllabic words. Although their performance on the judgement task was not significantly different to the AM children, their performance when asked to judge the accuracy of their own output errors suggested that their input phonological representations lacked the precision and accuracy of those of older children. Given that this participant group has just begun formal literacy education, this finding supports that of previous research (Bishop & Snowling, 2004) which suggests that phonological representations become more refined with the acquisition of literacy.

Clinical implications

This research has demonstrated the value of silent or judgement tasks as part of an assessment battery in order to investigate a child's input phonological representations. It has also highlighted the value of multisyllabic naming tasks in order to assess output phonological representations. Results of this study lead us to urge caution in interpreting speech errors as being indicative of underlying weakness with stored phonological representations, as for the typically-developing children in this study this was not always the case.

Individually designed assessment tasks where a child is asked to reflect on their own inaccurate productions open the window into stored phonological representations. Tasks of this nature measure the accuracy of the child's input phonological representation for individual words. There is a place for these

measures in the assessment of children for whom imprecise or fuzzy input phonological representations are indicated, as has been recommended by Stackhouse and Wells (1997). One such example described in the literature where a child is presented with their own output error is Locke's (1980) Speech Production-Perception Task in which a child is asked to judge the accuracy of his/her own erroneous forms. The results of our study support the use of such individually-designed assessment tasks in order to help determine to what degree speech errors are a result of speech output difficulties or a sign of poorly specified underlying phonological representations.

Acknowledgements

The authors would like to acknowledge Cori Williams, John Hogben, and Nick Barrett who provided valuable support throughout this project. We would also like to thank the schools who took part in this study and the children who participated so willingly in the project.

Declaration of interest: There are no conflicts of interest to be declared.

References

- Baker, E., & Munro, N. (2011). An overview of resources for assessing toddlers' productions of polysyllables. *ACQuiring Knowledge in Speech, Language, and Hearing*, 13, 58–63.
- Baker, E., Croot, K., McLeod, S., & Paul, R. (2001). Psycholinguistic models of speech development and their application to clinical practice. *Journal of Speech, Language, and Hearing Research*, 14, 685–702.
- Bishop, D., & Snowling, M. J. (2004). Developmental dyslexia and Specific Language Impairment: Same or different? *Psychological Bulletin*, 130, 858–886.
- Carroll, J. M., Snowling, M., Hulme, C., & Stevenson, J. (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, 39, 913–923.
- Claessen, M., & Leitão, S. (in press). Phonological representations in children with SLI. *Child Language Teaching and Therapy*, in press
- Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language and Communication Disorders*, 44, 121–144.
- Dollaghan, C. (1998). Spoken word recognition in children with specific language impairment. *Applied Psycholinguistics*, 19, 193–207.
- Edwards, J., & Lahey, M. (1998). Non word repetitions of children with specific language impairment: Exploration of some explanations for their inaccuracies. *Applied Psycholinguistics*, 19, 279–309.
- Elbro, C. (1998). When reading is "readn" or somthn. Distinctness of phonological representations of lexical items in normal and disabled readers. *Scandinavian Journal of Psychology*, 39, 149–153.
- Fisher, C., Hunt, C., Chambers, K., & Church, B. (2001). Abstraction and specificity in preschoolers' representations of novel spoken words. *Journal of Memory and Language*, 45, 665–687.
- Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, 29, 336–360.

- Griffiths, Y., & Snowling, M. (2001). Auditory word identification and phonological skills in dyslexic and average readers. *Applied Psycholinguistics*, 22, 419–439.
- Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Perception and Psychophysics*, 28, 267–283.
- Kan, P. & Windsor, J. (2010). Word learning in children with primary language impairment: A meta-analysis. *Journal of Speech Language and Hearing Research* 53, 739–756
- Leonard, L. (1998). *Children with Specific Language Impairment*. Massachusetts: MIT.
- Locke, J. (1980). The inference of speech perception in the phonologically disordered child. *Journal of Speech and Hearing Disorders*, 45, 431–467.
- Maillart, C., Schelstraete, M., & Hupet, M. (2004). Phonological representations in children with SLI: A study of French. *Journal of Speech, Language, and Hearing Research*, 47, 187–198.
- Mani, N., & Plunkett, K. (2007). Phonological specificity of vowels and consonants in early lexical representations. *Journal of Memory and Language*, 57, 252–272.
- Marshall, C., Ramus, F., & van der Lely, H. (2010). Do children with dyslexia and/or specific language impairment compensate for place assimilation? Insight into phonological grammar and representations. *Cognitive Neuropsychology*, 27, 563–586.
- Monsell, S. (1987). On the relation between lexical input and output pathways for speech. In A. Allport (Ed.), *Language perception and production* (pp. 273–311). London: Academic Press.
- Montgomery, J. W. (1999). Recognition of gated words by children with specific language impairment: An examination of lexical mapping. *Journal of Speech, Language, and Hearing Research*, 42, 735–743.
- Pennington, B. & Bishop, D. (2009). Relations among speech, language and reading disorders. *Annual review of Psychology*, 60, 283–306.
- Semel, E., Wiig, E., & Secord, W. (2003a). *Clinical Evaluation of Language Fundamentals - IV*. Marickville: Harcourt Assessment.
- Semel, E., Wiig, E., & Secord, W. (2003b). *Clinical Evaluation of Language Fundamentals - Fourth Edition Examiner's Manual*. Marickville: Harcourt Assessment.
- Shriberg, L., Austin, D., Lewis, B., McSweeney, J. & Wilson, D. (1997) The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language and Hearing Research* 40, 708–722.
- Snowling, M., van Wagtenonk, B., & Stafford, C. (1988). Object-naming deficits in developmental dyslexia. *Journal of Research in Reading*, 11, 67–85.
- Stackhouse, J., & Wells, B. (1997). *Children's speech and literacy difficulties: A psycholinguistic framework*. London: Whurr.
- Stackhouse, J., Vance, M., Pascoe, M., & Wells, B. (2007). *Children's speech and literacy difficulties: Compendium of auditory and speech tasks*. West Sussex: John Wiley & Sons.
- Sutherland, D. & Gillon, G. (2005). Assessment of phonological representations in children with speech impairment. *Language, Speech and Hearing Services in Schools* 36, 294–307.
- Swan, D., & Goswami, U. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, 66, 18–41.
- Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, 45, 2–40.
- Walley, A. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review*, 13, 286–350.
- Wechsler, D. (1991). *Wechsler Intelligence Scale for Children - Third Revision*. New York: The Psychological Corporation.
- Wechsler, D. (2004). *Wechsler Preschool and Primary Scale of Intelligence - Third Edition*. Cleveland, OH: Psychological Corporation.
- Wesseling, R., & Reitsma, P. (2001). Preschool phonological representations and development of reading skills. *Annals of Dyslexia*, 51, 203–229.
- White, K., & Morgan, J. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language*, 59, 114–132.

General discussion

The aim of this program of research was to explore how children with SLI process phonological information and thus to add to our understanding of the nature of the underlying deficit in SLI. The research is unique in a number of ways. Firstly, in contrast to most of the literature in the area, a broad range of phonological processing measures was included in the task battery. These tasks were carefully selected to allow analysis and interpretation using the speech processing model proposed by Stackhouse and Wells (1997). The task battery also included two recently developed receptive measures of phonological representations (Claessen et al., 2009; Claessen et al., 2010). In addition, in order to minimize the impact of the well-recognised heterogeneity in the population of children with SLI, tight selection criteria were employed and a comprehensive set of tasks was employed to ensure all participants with SLI met the DSM-IV (American Psychiatric Association, 1994) criteria for SLI. Finally, two comparison groups of children with typical language development were utilized as controls: one group of children matched closely for age, and a second group matched for receptive language skills. The inclusion of two groups of typically developing participants allowed for the SLI participants to be compared with each group of typically developing children and thus permitted a consideration of both language delay and language difference in specific language impairment.

Overall the findings of this program of research provided some support for a specific processing account of SLI. The children with SLI demonstrated significantly weaker

performance on tasks which required access to high quality phonological representations of multisyllabic words as well as both short term and working memory tasks.

Findings from the program of research will now be integrated and interpreted within the Stackhouse and Wells (1999) speech processing model considering input processing, lexical storage and output processing. Results will be discussed with specific reference to how the findings inform our understanding of the underlying deficit in SLI.

Input processing

Input processing skills were assessed using a range of both short term and working memory tasks. In general the children with SLI performed more poorly than typically developing children matched for age, however the comparison with typically developing children matched for receptive language skills was more complex.

Short-term memory was assessed using two measures, a number repetition forward task (Semel et al., 2003a) and a nonword repetition task (Dollaghan & Campbell, 1998). Repeating digits requires holding an item in memory, while waiting to hear all of the input, and then access the stored phonological representations, motor plans and motor programmes for the items prior to responding. On this task, the children with SLI demonstrated significantly weaker performance than either age matched or language matched groups. Given that the items in this task are short words which are well known by the participants, it is hypothesized that this reflects the weaker input processing and short term memory skills of the children with SLI.

The results of the nonword repetition test (Dollaghan & Campbell, 1998) were more surprising, with the SLI participants demonstrating significantly weaker performance than the age matched group but not the language matched group. Thus the ability to repeat nonwords appeared related to receptive language ability. This finding is in contrast to some of the literature where children with SLI were found to have poorer nonword repetition skills than language matched peers (Gathercole & Baddeley, 1990). As discussed in paper 4 (Claessen et al., in press) this may be a result of the nonword repetition task selected for this research which did not include any consonant clusters. Marshall and van der Lely (2009) suggested that children with SLI have particular difficulty repeating nonwords which contain a consonant cluster, and thus this was proposed as one explanation for the pattern of responses. Further attempts to understand this observation also revealed that the language-matched participants in this program of research had an average age of 5; 6 years which is younger than the age of the typically developing children in the study by Dollaghan and Campbell (1998) and, in fact, younger than the typically developing children in most of the studies included by Graf Estes, Evans, and Else-Quest (2007) in their meta-analysis. Therefore the lack of a significant difference between the SLI participants and the language-matched participants may be due to the task being too difficult for the younger children, which was supported by their scores on the task. Further research with a variety of nonword repetition tasks in typically developing children and children with SLI over wider ranges of ages is required to further investigate this finding.

Two measures of working memory were included in this program of research. SLI participants and age-matched peers completed a number repetition backwards task (Semel et al., 2003a) and the Competing Language Processing Task (Gaulin & Campbell, 1994). The younger language-matched peers did not complete the Competing Language Processing Task.

The SLI participants demonstrated weaker skills on the Competing Language Processing Task than AM peers. This suggests that less processing resources were available to complete the storage and processing tasks at the same time. And is in keeping with the findings of Petruccelli, Bavin and Bretherton (2012).

On the digits backward task (Semel et al., 2003a) a different pattern of results was observed with no difference found between the age-matched and SLI group, who both performed better than the language-matched group. When raw scores were examined it was revealed that this task was difficult for all groups of participants and the pattern of results may reflect the overall task difficulty for children aged between five and seven years of age. Petruccelli, et al (2012) found a similar pattern of results and reached the conclusion that the processing demands of this task are too difficult for 5 year old children. Thus in summary the children with SLI demonstrated significantly weaker skills in both short term and working memory than age matched peers. It is more difficult to draw conclusions between the children with SLI and language matched peers due to the processing demands of many of the tasks used in the programme of research.

Phonological representations

Phonological representations were assessed using two measures developed as part of this program of research the Quality of Phonological Representations (Claessen et al., 2009) and the Silent Deletion of Phonemes task (Claessen et al., 2010). While many other tasks included in the assessment battery require access to the phonological representations of items such as digits, and colours, they, however, have not been considered as sensitive measures of phonological representations as they are short, well learned items which have been carefully selected as items in tasks designed to measure memory, and rapid retrieval.

On the Quality of Phonological Representations, the SLI participants demonstrated significantly weaker performance than both groups of typically developing participants. In contrast, on the Silent Deletion of Phonemes, a developmental pattern of results was observed with younger children performing more poorly. There are key differences between the tasks, which may account for the pattern of results. The Quality of Phonological Representations task requires the child to hear the production of a multisyllabic word (input processing), hold this production in memory, and then match this production with a representation accessed from their store, which is triggered by seeing and recognising a picture. In this task a child makes a judgment about whether the heard production matches a stored representation of the word at the whole word level. The Silent Deletion of Phonemes also requires access to a stored phonological representation with no auditory input i.e it does not require input processing, but then requires the child to hold the representation in working memory while manipulating the sound code by removing a specified segment of the word, and

then selecting the picture that matches the new representation. All items in this task are either single syllable or compound words.

Key differences between the tasks are therefore the role played by input processing – which for the QPR requires comparing a word that is heard with one stored, while the SDOP does not require input processing, the reliance on phonological awareness in the Silent Deletion of Phonemes task compared to the whole word judgment in the Quality of Phonological Representations task and the use of multisyllabic words in the Quality of Phonological Representations task compared to the single syllable or compound words in the Silent Deletion of Phonemes Task. Thus the children with SLI have significantly greater difficulty developing fine grained representations for multisyllabic words than typically developing children, even those matched for language.

Output processing

Output measures for this programme of research included the multisyllabic word naming task (Claessen et al., 2009) and the rapid automatised naming task (Wagner et al., 1999). Both these tasks require the semantic recognition of a picture and then accessing of a stored phonological representation, motor plan and motor program in order to produce the name of the item. On the multisyllabic word naming task, when the measure of semantic accuracy was considered, all participants were able to name each of the words. When ability to say the words correctly was considered i.e. phonological accuracy, there was no significant difference between the AM and SLI groups who were both significantly more accurate than the LM group. On the rapid

naming task the AM group were significantly quicker than the SLI and LM groups, and the SLI group were significantly quicker than the LM group.

These findings suggest that the SLI group were able to retrieve motor programs for multisyllabic words as accurately as their age-matched peers, however on the speeded task they were significantly slower. This suggests that accurate motor programs have been developed and stored, even for the multisyllabic words but that processing time is longer. The inconsistent findings between judgment and production of multisyllabic words for all participants is consistent with models of speech processing (Monsell, 1987; Stackhouse & Wells, 1997) which propose separate input and output phonological representations. Drawing on the processing requirements of the tasks, allows some consideration of these differences. In order to complete the judgment task, there would be no requirement to access the output phonological representation, while in order to complete the output, picture naming task, the child would need to access a stored semantic representation, their output phonological representation and motor programme.

The phonological awareness measure selected for this program of research was the Sutherland Phonological Awareness Test (Neilson, 2003). This measure was chosen as it is commonly used by Australian speech pathologists, and normative data is available for the Australian population. Similar to the Silent Deletion of Phonemes measure, a developmental pattern of results was found with the Phonological Awareness measure. The task selected includes a range of subtests such as rhyme judgment and generation and onset identification and deletion. Therefore this task draws on a range of processing routes, input, representations and output across most

of the subtests. While the children with SLI demonstrated significantly weaker performance than the age matched group, their performance was significantly better than the language matched group. This pattern is consistent with research by Zirou et al (2010) who found that the phonological awareness skills of children with SLI improved with literacy teaching and phonological awareness intervention.

Theoretical implications

The mapping theory proposed by Chiat (2001) is one example of a processing theory which highlights the importance of phonological processing skills in the acquisition of language. This theory proposes that development in vocabulary and syntax relies on phonological information being accurately perceived and represented in order to establish strong links between semantic and phonological representations of words. Overall the findings of this program of research provided some support for a specific processing account of SLI with the SLI participants having significantly weaker performance than age-matched peers on short term and working memory tasks as well as tasks which required access to high quality phonological representations of multisyllabic words.

The finding that children with SLI demonstrated weaknesses in both phonological short term memory and working memory tasks supports previous research, and the suggestion that the underlying deficit in SLI may at least partially lie with memory (Schwartz, 2009). Both short term and working memory skills are vital in the process of learning language. The acquisition of language, including the development of phonological representations involves processing input and information being held in the phonological loop while precise, well-defined lexical representations are

developed. This is particularly important in the process of learning new words where the new representation must be finely grained enough to distinguish it from previously stored items.

In this program of research the participants with SLI demonstrated a relative strength in phonological awareness and the ability to internally segment stored phonological representations, and a relative weakness in the quality of underlying stored phonological representations particularly for longer words.

The difference in findings between the two measures of phonological representations may be a result of different task demands. On the Silent Deletion of Phonemes task participants are able to select the correct response from an array of four pictures, based on accessing their underlying representations. On the Quality of Phonological Representations task participants are required to indicate whether a production is accurate or not, and match the heard word to their own representation. Thus a more accurate representation of the word is required in order to correctly reject a production, which may only differ, by one dimension of one phoneme (e.g. is this a ¹teləvɪʒəm, or is this a ¹deləvɪʒən). Carroll and Myer (2011) suggest that such a task places a great demand on the quality of the phonological representation, as individual phonemes within a word must be attended to. They suggest that before literacy exposure, phonological representations may be stored using acoustic information

The lexical restructuring hypothesis proposes that representations are initially holistic, but that they become more refined as the vocabulary increases and with the acquisition of literacy. An alternative view (Coady and Aslin 2004) is that young children have phonological representations that are segmental in nature, but that they lack the attention, memory and processing abilities to successfully complete some tasks. In their study, Coady and Aslin (2004) found that young children (2; 6 -3; 6) were sensitive to the frequency of individual segments within nonwords supporting the notion of fine-grained representations. This viewpoint offers the suggestion that the younger language matched group, indeed had well segmented phonological representations, as indicated by their performance on the QPR, however their weaker PA skills, as indicated by performance on the SPAT-R indicates they were not able to explicitly use segmental processing skills to demonstrate the quality of their underlying stored phonological representations on the QPR (Foy and Mann 2009).

The relationship between stored phonological representations and phonological awareness has been investigated by a number of researchers. For example, Rvachew, Nowak, and Cloutier (2004) used a silent word judgment task, with feedback provided for inaccurate responses, as an adjunct to phonological therapy to investigate whether improving the quality of stored phonological representations would result in improved phonological awareness skills. After a period of therapy, improvement was observed on measures of phonology, but not phonological awareness. One explanation offered for this result is that in order to be able to complete phonological awareness tasks, one must be able to reflect on the structure of the stored words. In this study, the participants were provided with therapy to improve the quality of their phonological

representations and their phonology, however there was no explicit teaching of metalinguistic skills. This may explain the lack of improvement in phonological awareness despite the improvement in phonology itself. This hypothesis is supported by Swan and Goswami (1997) who propose that strong phonological awareness skills may be a consequence of phonological representations which are both accurate and organized by segmental structure of words. The relationship between phonological awareness and stored phonological representations in typically developing children was discussed in paper 1 (Claessen et al., 2009). It was reported that, for typically developing children “performing poorly on the QPR task usually indicated poor PA” (Claessen et al., 2009, p. 136).

All the SLI participants in this program of research were attending a Language Development Centre and were receiving intensive intervention including phonological awareness programs. The effectiveness of these evidence based programmes may partially explain the relatively strong performances by the SLI participants on the phonological awareness and the Silent Deletion of Phonemes tasks however did not result in improvement in the quality of underlying stored phonological representations as reflected by performance on the QPR.

It may be that the children with SLI had learnt to complete the phonological awareness tasks, and thus had improved metalinguistic skills, but that this was more a learned metacognitive skill rather than the result of increased quality of the underlying stored phonological representations. Perhaps the observed weakness in phonological and working memory may be impacting on the ability to develop well specified, high quality phonological representations especially of longer and more complex words.

Another possible explanation is that children with SLI have more difficulty laying down accurate phonological representations for multisyllabic words than for shorter words. Processing and developing phonological representations for multisyllabic words places increased pressure on working memory and the phonological loop, known to be weaker in this population, and as a result less accurate representations may be developed. Tasks to measure phonological awareness generally include only single syllable words, and this may mask residual imprecision in the phonological representations of such words.

A deficit in phonological and working memory and in establishing well specified lexical representations may explain the myriad of symptoms found in the SLI population. For example, the well documented difficulty in learning new words may be the result of difficulty developing well accurate, well-specified phonological and semantic representations and developing strong links between the two (Alt & Plante, 2006; Sheng & McGregor, 2010). The finding that children with SLI were able to identify each item in the QPR and SDOP suggests that initial mapping of the word has taken place. However their difficulty with rejecting erroneous productions of the words, and acceptance of their own inaccurate productions as correct, suggests their representations are not as well specified as those of typically developing children.

Translation to practice

In order to develop a comprehensive understanding of the speech processing skills of children presenting with language and/or literacy weaknesses, it is important that the assessment battery contains tasks which assess a range of speech processing skills.

The Quality of Phonological Representations and Silent Deletion of Phonemes tasks

developed in this program of research allow clinicians to assess the quality and accuracy of a child's stored phonological representations without requiring spoken output. Such tools are important for all clinicians, especially those working with children with speech sound impairments, or those who use augmentative communication.

In addition to supporting the finding that children with SLI have difficulty with phonological processing, this research provided further evidence of the heterogeneity of SLI, despite tight selection criteria. Such findings highlight the need for individualized assessment and intervention. The use of a theoretical model to design assessment tasks and subsequent intervention will continue to develop the evidence base for intervention with such clients. In order to disseminate the results of this research to clinicians, who are consumers of research, paper three was published as a summary of findings on two clinically relevant tasks, and interpreted using a theoretical model.

The SLI participants had been involved in intensive therapy focusing on phonological awareness skills, and while the intervention is hypothesised to have led to stronger skills on the tasks which require phonological awareness skills, it did not appear to have a similar impact on the underlying phonological representations. Thus when planning intervention for children with SLI, clinicians need to consider how to facilitate the development and storage of underlying phonological representations, as well as teaching phonological awareness skills. Rees (2001) highlights the importance of strengthening links between different forms of representations in the lexicon in therapy and provides strategies that can be used in implementing such an approach.

Given the identified weakness with short term and working memory there may be value in considering the memory demands of therapy tasks. The effectiveness of therapy may be improved by reducing the memory demands of tasks, using strategies such as short utterances, stressing key words and perhaps using visual scaffolds. The majority of phonological awareness programs contain single or two syllable items, rather than multisyllabic word items. The demonstrated difficulty children with SLI have with developing accurate representations of multisyllabic words highlights the need for items within phonological awareness programs to include multisyllabic words to assist children develop finely grained representations.

Limitations

While this program of research has made a significant contribution to our knowledge and understanding of specific language impairment, there are a number of limitations that must be acknowledged. A major focus of this research was to employ tight selection criteria to ensure all participants met the DSM-IV (American Psychiatric Association, 1994) criteria for SLI. It was hypothesized that this might reduce some of the previously observed heterogeneity, however it resulted in only 21 participants in the SLI group, and despite the tight selection criteria, heterogeneity still existed within the SLI participants.

All participants with SLI were drawn from the one school in Western Australia. While this reduced some heterogeneity within the group it does limit how well results of this research can be generalised to other children with SLI. In addition the participants with SLI received classroom based language intervention prior to the study and continued to do so throughout data collection. While the impact of such language

intervention on phonological awareness skill has been acknowledged throughout, the impact on other language domains is unknown.

Another focus of the program of research was to collect information on a full battery of phonological processing skills. The link between phonological processing skills and literacy development is well researched for typically developing children (Catts, Fey, Zhang, & Tomblin, 2001; Snowling, 2000a, 2000b) and children with reading difficulties (Boada & Pennington, 2006). This program of research offered an opportunity to explore the link between phonological processing skills and literacy development in a tight knit group of children with SLI. Much research has also focused on the overlap and co-existence of SLI and dyslexia (Catts, Adlof, Hogan, & Ellis Weismer, 2005; Pennington & Bishop, 2009) however due to the age of the participants and the amount of data that was already being collected a decision was made to focus on phonological processing skills rather than to include additional literacy measures.

Future directions

This program of research has added significantly to our knowledge of phonological processing skills in specific language impairment. There are a number of areas which require further research.

Despite the tight participant selection criteria employed in this program of research, there was still a significant amount of heterogeneity evidenced within the SLI participant group. This requires further investigation. A larger participant pool would

allow researchers to explore the existence of subgroups within the current diagnostic category of SLI.

As acknowledged above, data was not collected on any measures of literacy. Given the overlap between dyslexia and specific language impairment is well documented, as such future research should focus on the relationship between dyslexia and specific language impairment and the role of phonological processing skills in each.

The current research highlighted the weakness in phonological and working memory and the quality of stored phonological representations. Future research is required to explore the relationship between the ability to learn new words and phonological processing skills particularly in the acquisition of new multisyllabic words. The Quality of Phonological Representations Task and the Silent Deletion of Phonemes Task were both valid and reliable tools for pre-school children. Future research should also address the need for similar tasks in younger children in order to identify children at risk for later language and literacy difficulties.

Children with SLI were identified as having particularly poor quality representations of multisyllabic words and thus future research is required to investigate how to improve the quality of such underlying stored representations. In this research it was identified that phonological awareness programs, appear to improve phonological awareness skills, yet the impact was less obvious on the underlying representation. Future research is required to identify effective strategies to improve the phonological representations at all word lengths, which are vital for literacy.

Conclusion

This program of research has drawn on a speech processing model (Stackhouse & Wells, 1997) to explore the phonological processing skills of a tightly defined group of children with SLI. A range of phonological processing measures were included in this research, including two innovative tasks (Claessen et al., 2009; Claessen et al., 2010) designed to assess the quality and accuracy of stored phonological representations without requiring spoken output. In addition, two comparison groups of typically developing children were recruited, one group matched for age and gender, and the other matched for gender and receptive language skills facilitated consideration of both language delay and language difference in specific language impairment.

The children with SLI demonstrated an interesting pattern of phonological processing skills, with particular difficulty observed in phonological and working memory.

Children with SLI also evidenced lower quality stored phonological representations of multisyllabic words. Performance on measures of phonological awareness was relatively strong indicating that such skills can be taught, but that improvement in this area does not necessarily improve the quality of the underlying phonological representation.

This research highlighted the heterogeneity within Specific Language Impairment. It provided some support for a specific processing account on SLI and highlighted the importance of phonological and working memory in the development of accurate phonological representations.

List of references

- Aguilar-Mediavella, E., Sanz-Torrent, T., & Serra-Raventos, M. (2002). A comparative study of the phonology of pre-school children with specific language impairment (SLI), language delay (LD) and normal acquisition. *Clinical linguistics and phonetics*, 16(8), 573-596. doi: 10.1080/02699200210148394
- Alt, M., & Plante, E. (2006). Factors that influence lexical and semantic fast mapping of young children with specific language impairment. *Journal of Speech and Hearing Research*, 49(5), 941-954. doi: 10.1044/1092-4388(2006/068
- Archibald, L., & Gathercole, S. (2006). Short term and working memory in specific language impairment. *International Journal of Language and Communication Disorders*, 41(6), 675-693. doi: 10.1080/13682820500442602
- Association, A. P. (1994). *Diagnostic and statistical manual of mental disorders - Fourth edition* (4 ed.). Washington: American Psychiatric Association.
- Bishop, D. (1997). *Uncommon understanding: Development and disorders of language comprehension in children*. Hove: Psychology Press.
- Botting, N., & Conti-Ramsden, G. (2001). Non-word repetition and language development in children with specific language impairment (SLI). *International Journal of Communication Disorders*, 36(4), 421-432. doi: 10.1080/13682820110074971

Carroll, J. & Myers, J. (2011). Spoken word classification in children and adults.

Journal of Speech, Language and Hearing Research, 54 (2) 127-147.

doi:10.1044/1092-4388(2010/08-0148)

Catts, H., Fey, M., Zhang, X., & Tomblin, B. (2001). Estimating the risk of future reading difficulties in kindergarten children: A research-based model and its clinical implementation. *Language, Speech & Hearing Services in Schools.*, 32(1), 38-50. doi:

10.1044/0161-1461(2001/004)

Chiat, S. (2000). *Understanding Children with Language Problems*. Cambridge: Cambridge University Press.

Chiat, S. (2001). Mapping theories of developmental language impairment: Premises, predictions and evidence. *Language and Cognitive Processes*, 16(2/3), 113-142. doi:

10.1080/01690960042000012

Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language & Communication Disorders*, 44(2), 121-144. doi:

10.1080/13682820801966317

Claessen, M., & Leitão, S. (2012a) Phonological representations in children with SLI. *Child Language Teaching and Therapy* 28(2), 211-223. doi:

10.1177/0265659012436851

Claessen, M., & Leitão, S. (2012b). The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14(3), 226-234. doi: 10.3109/17549507.2012.679312

Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language & Communication Disorders*, 45(4), 411-423. doi: 10.1080/13682820903111945

Claessen, M., Leitão, S., Kane, R., & Williams, C. (in press). Phonological processing skills in Specific Language Impairment. *International Journal of Speech - Language Pathology*.

Coady, J. & Aslin, R. (2004). Young children's sensitivity to probabilistic phonotactics in the developing lexicon. *Journal of Experimental Child Psychology*, 89, 183-213. doi: 10.1016/j.jecp.2004.07.004.

Conti-Ramsden, G., Botting, N., Simkin, Z., & Knox, E. (2001). Follow-up of children attending infant language units: outcomes at 11 years of age. *International Journal of Language and Communication Disorders*, 36(2), 207-219. doi: 10.1080/13682820121213

Conti-Ramsden, G., Crutchley, A., & Botting, N. (1997). The extent to which psychometric tests differentiate subgroups of children with SLI. *Journal of Speech, Language and Hearing Research*, 40(4), 765-777. doi: <http://jslhr.asha.org>

Dollaghan, C., & Campbell, T. F. (1998). Nonword Repetition and Child Language Impairment. *Journal of Speech, Language, and Hearing Research, 41*(5), 1136-1146. doi: <http://jslhr.asha.org>

Ellis Weismer, S. E., Evans, J., & Hesketh, L. J. (1999). An Examination of Verbal Working Memory Capacity in Children With Specific Language Impairment. *Journal Of Speech Language and Hearing Research, 42*, 1249-1260. doi: <http://jslhr.asha.org>

Ellis Weismer, S. E., Tomblin, B., Zhang, X., Buckwalter, P., Chynoweth, J., & Jones, M. (2000). Nonword repetition performance in school-aged children with and without language impairment. *Journal of Speech, Language and Hearing Research, 43*(4), 865-878. doi: <http://jslhr.asha.org>

Foy, J. & Mann, V. (2009). Effects of onset density in preschool children: Implications for development of phonological awareness and phonological representation. *Applied Psycholinguistics, 30* (2), 339-361. doi:10.1017/S0142716409090146

Gathercole, S. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied psycholinguistics, 27*, 513-543. doi: 10.1017/S0142716406060383

Gathercole, S., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336-360. doi: 10.1016/0749-596X(90)90004

Gaulin, C., & Campbell, T. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual and Motor Skills*, 79, 55-64. doi: 10.2466/pms.1994.79.1.55

Graf Estes, K., Evans, J. L., & Else-Quest, N. L. (2007). Differences in the Nonword Repetition Performance of Children With and Without Specific Language Impairment: A Meta-Analysis. *Journal of Speech, Language, and Hearing Research*, 50(1), 177-196. doi: 10.1044/1092-4388(2007/015)

Griffiths, Y., & Snowling, M. (2001). Auditory word identification and phonological skills in dyslexic and average readers. *Applied Psycholinguistics*, 22(3), 419-439. doi: <http://dx.doi.org/>

Leonard, L. (1998). *Children with Specific Language Impairment*. Massachusetts: MIT.

Leonard, L., Weismer, S., Miller, C., Francis, D., Tomblin, B., & Kail, R. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech and Hearing Research*. doi: 10.11044/1092-4388(2007.029)

Marton, K., & Schwartz, R. G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, 46, 1138-1153. doi: 10.1044/1092-4388(2003/089)

Miller, C. A., Kail, R., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech Language and Hearing Research*, 44, 416-433. doi: 10.1044/1092-4388(2001/034)

Monzell, S. (1987). On the relation between lexical input and output pathways for speech. In A. Allport (Ed.), *Language Perception and Production* (pp. 273-311). London: Academic Press.

Neilson, R. (2003). *Sutherland Phonological Awareness Test - Revised*. Jamberoo, NSW: Language Speech and Literacy Services.

Petrucelli, N., Bavin, E. & Bretherton, L. (2012) Children with specific language impairment and resolved late talkers: working memory profiles at 5 years. *Journal of Speech, Language and Hearing Research*, 55 (6) 1690 – 1703. doi: 10.1044/1092-4388(2012/11-0288

Rees, R. (2001). Principles of Psycholinguistic Intervention. In Stackhouse, J and Wells, B (Ed), *Children's Speech and Literacy Difficulties: Identification and Intervention* (pp. 41-65). London:Whurr.

Rice, M., & Wexler, K. (1996). Toward Tense as a Clinical Marker of Specific Language Impairment in English-Speaking Children. *Journal of Speech and Hearing Research*, 39, 1239-1257. doi: <http://jslhr.asha.org/cgi/content/abstract/39/6/1239>

Rvachew, S., Nowak, M., & Cloutier, G. (2004). Effect of Phonemic Perception Training on the Speech Production and Phonological Awareness Skills of Children With Expressive Phonological Delay. *American Journal of Speech - Language Pathology*, 13(3), 250-263. doi: doi:10.1044/1058-0360(2004/026)

Schwartz, R. (2009). Specific Language Impairment. In R. Schwartz (Ed.), *Handbook of child language disorders*. New York: Psychology Press.

- Semel, E., Wiig, E., & Secord, W. (2003). *Clinical Evaluation of Language Fundamentals - IV: The Psychological Corporation*. Harcourt Brace Jovanovich, Inc.
- Sheng, L., & McGregor, K. (2010). Lexical-semantic organisation in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, 53(1), 146-159. doi: 10.1044/1092-4388(2009/08-0160)
- Snowling, M. (2000a). *Dyslexia*. Oxford: Blackwell publishers.
- Snowling, M. (2000b). Language and literacy skills: Who is at risk and why? In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 245-260). Hove, UK: Psychology Press.
- Stackhouse, J., & Wells, B. (1997). *Children's Speech and Literacy Difficulties, A Psycholinguistic Framework*. London: Whurr.
- Sutherland, D., & Gillon, G. (2005). Assessment of phonological representations in children with speech impairment. *Language Speech and Hearing Services in Schools*, 36(4), 294-310. doi: 10.1044/0161-1461(2005/030)
- Swan, D., & Goswami, U. (1997). Phonological Awareness Deficits in Developmental Dyslexia and the Phonological Representations Hypothesis. *Journal of Experimental Child Psychology*, 66, 18-41.
- Torgesen, J., Wagner, R., & Rashotte, C. (1994). Longitudinal studies of phonological processing and reading. [Research Support, U.S. Gov't, P.H.S.]. *Journal of Learning Disabilities*, 27(5), 276-286. doi: 10.1177/002221949402700503

Van der Lely, H., Rosen, S., & McClelland, A. (1998). Evidence for a grammar-specific deficit in children. *Current Biology*, 8(23), 1253-1258. doi: 10.1016/S0960-9822(07)00534-9

Vanderwalle, E., Boets, B., Ghesquiere, P., & Zink, I. (2010). Who is at risk for dyslexia? Phonological processing in five-to-seven-year old Dutch speaking children with SLI. *Scientific studies of reading*, 14(1), 58-84. doi: 10.1080/10888430903242035

Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101(2), 192-212. doi: 10.1037/0033-2909.101.2.192

Wagner, R., Torgesen, J., & Rashotte, C. (1999). *Comprehensive Test of Phonological Processes*. Austin: Pro-Ed.

Zirou, F., Ecalle, J., Magnan, A & Sanchez, M (2010). The fragile nature of phonological awareness in children with specific language impairment: Evidence from literacy development. *Child Language Teaching and Therapy* 26 (3), 347-358. Doi: 10.1177/0265659010369288

Appendices

APPENDIX 1 –Quality of phonological representations task

Instructions:

You're going to see some pictures on the computer and hear the names of the pictures.

Sometimes you will hear the names said the right way but sometimes they will be a bit wrong. Your job is to click on this green button when the name is right, and click on this red button when the name is a bit wrong.

Are you ready, let's start.....

Make sure the child returns the mouse to the centre of the screen before pressing

ENTER to display the next picture.

Non-specific feedback should be given after each item. For example: well done, good boy/girl, you're doing a great job.

Item	Pseudowords
Training A: Boomerang	^l bɔməræŋg
	^l bubəræŋg
	^l puməræŋg
	^l bunəræŋ
	^l bumərɒŋg
	^l bɔməræŋg

Training B: Ambulance	ˈambuləns
	ˈæmpuləns
	ˈænbuləns
	ˈæmuləns
	ˈæmpulɔns
	ˈʌmbuləns
1. Helicopter	ˈhelikɒptə
	ˈhelikʊptʌ
	ˈhekilɒptə
	ˈhewikɒptə
	ˈhɪlikɒptʌ
	ˈhelitɒptə
2. Telescope	ˈteliskɒp
	ˈtelislɒp
	ˈtɪliskɒp
	ˈteliskɔʊb
	ˈtewiskɒp
	ˈtɒliskɒp
3. Dominoes	ˈdɒmɪnɔz

	¹ dɒmænoʊz
	¹ dɒmnoʊz
	¹ tɒmnoʊz
	¹ dɒmisoʊz
	dɒmnoʊz
4. Crocodile	¹ krɒkədɪl
	¹ krɒkətɑɪl
	¹ kɒkədɑɪl
	¹ krækədɑɪl
	¹ krɒkədɑɪl
	krɒtədɑɪl
5. Television	¹ tɪləvɪʒən
	¹ deləvɪʒən
	¹ tesəvɪʒən
	¹ teləvɪʒəm
	¹ teləvɪʒən
	tɪləvɪʒən
6. Hippopotamus	¹ hɪpəpɪtəməs
	¹ hɪtəpɪtəməs
	¹ hepəpɪtəməs

	^l hɪbəpətəməs
	^l hɪpəpetəməs
	^l hɪpəpətəpəs
7. Binoculars	^l bɑɪnɔkjuləz
	^l bɑɪnɔkjuləz
	^l bɑɪnɔɡjuləz
	^l bɑɪnɔkliəz
	^l bɑɪnɔkjuləz
	^l bɑɪnɔkjuləz
8. Microphone	^l mækrəfəʊn
	^l mɑɪkwəfəʊn
	^l mɑɪkrəfʊn
	^l mɑɪgrəfəʊn
	^l mɑɪkrəfɒn
	mɑɪkrəfəʊm
9. Rhinoceros	^l rɑɪnɔtərəs
	^l rɑɪnɔsərəs
	^l rɑɪnɔsərəz
	^l rɑɪnɔsərəs
	^l rɑɪnæsərəs

	'ramɔsərəs
10. Spaghetti	spə'geki
	bə'sgeti
	spə'giti
	spə'keti
	spə'gɒti
	pə'sgeti

Appendix 2 –Silent deletion of phonemes task

Instructions

For each item the child sees a picture on a computer screen and is asked to “look at this picture and think of the name of, but don’t say it out loud” e.g. switch.

They are then asked ‘now what word would it make if I took away the XX sound’, for example, took away the ‘s’ sound. They then see a computer screen consisting of four pictures—the correct response (witch), a semantic foil (light) and two phonological foils (swing and watch) (Figure 3). The child indicates their answer using the computer mouse.

Training Items

Stimulus	Instruction	Target	Phono distractor	Phono distractor	Semantic distractor
1 Teapot	Delete tea	Pot	Cot	Tea	Kettle
2 Earring	Delete ring	Ear	Ring	Beer	Head

Syllable Level

Stimulus	Instruct	Target	Phono distractor	Phono distractor	Semantic distractor
1 Football	Delete foot (1)	Ball	Wall	Foot	Basketball
2 Starfish	Delete fish (2)	Star	Car	Fish	Octopus
3 Eggcup	Delete cup (2)	Egg	Leg	Cup	Spoon
4 Cowboy	Delete boy (2)	Cow	Cloud	Boy	Sheep

5 Toothbrush	Delete tooth (1)	Brush	Bus	Tooth	Toothpaste
--------------	------------------	-------	-----	-------	------------

Onset-rime

Stimulus	Instruction	Target	Phono distractor	Phono distractor	Semantic distractor
Tie	Delete t	Eye	Pie	Tyre	Hat
Feet	Delete f	Eat	Meat	Wheat	Shoe
Leg	Delete l	Egg	Peg	Log	Arm
Dice	Delete d	Ice	Mice	Dive	Game
Gate	Delete g	Eight	Plate	Game	Cage

Phoneme - Final Sound

Stimulus	Instruction	Target	Phono distractor	Phono distractor	Semantic distractor
1 Cart	Delete t	Car	Dart	Heart	Horse
2 Beak	Delete k	Bee	E	Key	Bird
3 Sword	Delete d	Saw	Four	Door	Knight
4 Fork	Delete k	Four	Saw	Farm	Knife
5 Pies	Delete z	Pie	Eyes	Peas	Sauce

Phoneme - WICI

Stimulus	Instruct	Target	Phono distractor	Phono distractor	Semantic distractor
1 Ski	Delete s	Key	C	Sky	Sled
2 Train	Delete t	Rain	Crane	Tray	Bus
3 Switch	Delete s	Witch	Swing	Watch	Light
4 Swing	Delete s	Wing	Ring	Swim	Slide
5 Block	Delete b	Lock	Black	Clock	Dice

Phoneme - WICF

Stimulus	Instruct	Target	Phono distractor	Phono distractor	Semantic distractor
1 Bread	Delete r	Bed	Red	Head	Cake
2 Snail	Delete n	Sail	Nail	Snake	Beetle
3 Black	Delete l	Back	Sack	Block	Grey
4 Blocks	Delete l	Box	Lock	Socks	Toy
5 Clap	Delete l	Cap	Clip	Map	Hand

Phoneme - WFCI

Stimulus	Instruct	Target	Phono distractor	Phono distractor	Semantic distractor
1 Sand	Delete n	Sad	Hand	Sack	Sand Castle
2 Nest	Delete s	Net	Neck	Knot	Bird
3 Trains	Delete n	Trays	Hay	Tray	Buses
4 Pump	Delete m	Pup	Plum	Cup	Bike
5 Ghost	Delete s	Goat	Coat	Toast	Witch

Phoneme - WFCF

Stimulus	Instruct	Target	Phono distractor	Phono distractor	Semantic distractor
1 Lamp	Delete p	Lamb	Cap	Stamp	Table
2 Belt	Delete t	Bell	Bed	Head	Jeans
3 Gold	Delete d	Goal	Bowl	Foal	Silver
4 Shelf	Delete f	Shell	Bell	Well	Desk
5 Wink	Delete k	Wing	Pink	One	Blink

Appendix 3: Statement from co-authors

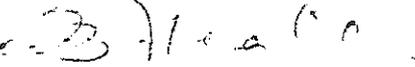
Paper 1:

To Whom It May Concern

I, Mary Elizabeth Claessen, was responsible for design and development of the Quality of Phonological Representations Task and contributed to the literature review, data analysis and drafting and writing the article for the paper: Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitao, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language & Communication Disorders*, 44(2), 121-144.

I, as a Co-Author, endorse that this level of contribution by the candidate indicated above is appropriate.

Steve Heath
(Full Name of Co-Author 1)



(Signature of Co-Author 1)

Janet Fletcher
(Full Name of Co-Author 2)



(Signature of Co-Author 2)

John Hogben
(Full Name of Co-Author 3)



(Signature of Co-Author 3)

Susan Karen Leitao
(Full Name of Co-Author 4)



(Signature of Co-Author 4)

Paper 2:

To Whom It May Concern

I, Mary Elizabeth Claessen, was responsible for design and development of the Silent Deletion of Phonemes Task, participant recruitment, data collection and interpretation, reviewing the literature and drafting and writing the article for the paper: Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language and Communication Disorders*, 45(4), 411-423.

I, as a Co-Author, endorse that this level of contribution by the candidate indicated above is appropriate.

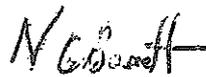
Susan Karen Leitão



(Full Name of Co-Author 1)

(Signature of Co-Author 1)

Nicholas Barrett



(Full Name of Co-Author 2)

(Signature of Co-Author 2)

Paper 3

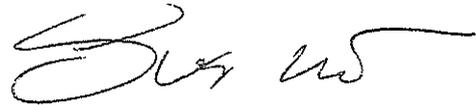
To Whom It May Concern

I, Mary Elizabeth Claessen, was responsible for developing the concept and design of the study, participant recruitment, data collection, analysis and interpretation, reviewing the literature and drafting and writing the article for the paper: Claessen, M. & Leitão, S. (2012) Phonological representations in children with SLI. *Child Language Teaching and Therapy*, 28 (2), 211-224.

I, as a Co-Author, endorse that this level of contribution by the candidate indicated above is appropriate.

Susan Karen Leitão

(Full Name of Co-Author 1)



(Signature of Co-Author 1)

Paper 4:

To Whom It May Concern

I, Mary Elizabeth Claessen, was responsible for developing the concept and design of the study, participant recruitment, data collection, analysis and interpretation, reviewing the literature and drafting and writing the article for the paper: Claessen, M., Leitão, S., Kane, R. & Williams, C. (in press) Phonological processing skills in Specific Language Impairment. *International Journal of Speech-Language Pathology*.

I, as a Co-Author, endorse that this level of contribution by the candidate indicated above is appropriate.

Susan Karen Leitão

(Full Name of Co-Author 1)



(Signature of Co-Author 1)

Robert Thomas Kane

(Full Name of Co-Author 2)



(Signature of Co-Author 2)

Corinne Jann Williams

(Full Name of Co-Author 3)



(Signature of Co-Author 3)

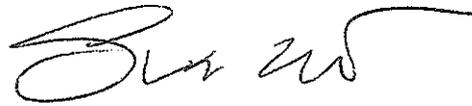
Paper 5:

To Whom It May Concern

I, Mary Elizabeth Claessen, was responsible for developing the concept and design of the study, participant recruitment, data collection analysis and interpretation, reviewing the literature and drafting and writing the article for the paper: Claessen, M. and Leitão, S. (2012) The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14 (3) 226-234

I, as a Co-Author, endorse that this level of contribution by the candidate indicated above is appropriate.

Susan Karen Leitão



(Full Name of Co-Author 1)

(Signature of Co-Author 1)

Appendix 4: Evidence of acceptance for paper 4.

22-Nov-2012

Dear Mary

Ref: Phonological processing skills in Specific Language Impairment

I have now considered your revised paper and have recommended publication in International Journal of Speech-Language Pathology. Congratulations! I am pleased to accept your paper in its current form which will now be forwarded to the publisher for copy editing and typesetting.

You will receive proofs for checking, and instructions for transfer of copyright in due course.

The publisher also requests that proofs are checked and returned within 48 hours of receipt.

Thank you for your contribution to International Journal of Speech-Language Pathology and we look forward to receiving further submissions from you.

Sincerely,
Sharynne

Professor Sharynne McLeod
Editor, International Journal of Speech-
Language Pathology
ijslp@csu.edu.au

Appendix 5: Permission letters regarding copyright.

Paper 1

JOHN WILEY AND SONS LICENSE TERMS AND CONDITIONS

Feb 09, 2013

This is a License Agreement between Mary Claessen ("You") and John Wiley and Sons ("John Wiley and Sons") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by John Wiley and Sons, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

[License Number](#)

3065921509786

[License date](#)

Jan 11, 2013

[Licensed content publisher](#)

John Wiley and Sons

[Licensed content publication](#)

International Journal of Language & Communication Disorders

[Licensed content title](#)

Quality of phonological representations: a window into the lexicon?

[Licensed copyright line](#)

2009 Royal College of Speech & Language Therapists

[Licensed content author](#)

Mary Claessen, Steve Heath, Janet Fletcher, John Hogben, Suze Leitão

[Licensed content date](#)

Dec 31, 2010

[Start page](#)

121

[End page](#)

144

[Type of use](#)

Dissertation/Thesis

[Requestor type](#)

Author of this Wiley article

[Format](#)

Print and electronic

[Portion](#)

Full article

[Will you be translating?](#)

No

[Total](#)

0.00 USD

Terms and Conditions

TERMS AND CONDITIONS

This copyrighted material is owned by or exclusively licensed to John Wiley & Sons, Inc. or one of its group companies (each a "Wiley Company") or a society for whom a Wiley Company has exclusive publishing rights in relation to a particular journal (collectively WILEY"). By clicking "accept" in connection with completing this licensing transaction, you agree that the following terms and conditions apply to this transaction (along with the billing and payment terms and conditions established by the Copyright Clearance Center Inc., ("CCC's Billing and Payment terms and conditions"), at the time that you opened your Rightslink account (these are available at any time at <http://myaccount.copyright.com>)

Terms and Conditions

1. The materials you have requested permission to reproduce (the "Materials") are protected by copyright.
2. You are hereby granted a personal, non-exclusive, non-sublicensable, non-transferable, worldwide, limited license to reproduce the Materials for the purpose specified in the licensing process. This license is for a one-time use only with a maximum distribution equal to the number that you identified in the licensing process. Any form of republication granted by this licence must be completed within two years of the date of the grant of this licence (although copies prepared before may be distributed thereafter). The Materials shall not be used in any other manner or for any other purpose. Permission is granted subject to an appropriate acknowledgement given to the author, title of the material/book/journal and the publisher. You shall also duplicate the copyright notice that appears in the Wiley publication in your use of the Material. Permission is also granted on the understanding that nowhere in the text is a previously published source acknowledged for all or part of this Material. Any third party material is expressly excluded from this permission.
3. With respect to the Materials, all rights are reserved. Except as expressly granted by the terms of the license, no part of the Materials may be copied, modified, adapted (except for minor reformatting required by the new Publication), translated, reproduced, transferred or distributed, in any form or by any means, and no derivative works may be made based on the Materials without the prior permission of the respective copyright owner. You may not alter, remove or suppress in any manner any copyright, trademark or other notices displayed by the Materials. You may not license, rent, sell, loan, lease, pledge, offer as security, transfer or assign the Materials, or any of the rights granted to you hereunder to any other person.
4. The Materials and all of the intellectual property rights therein shall at all times remain the exclusive property of John Wiley & Sons Inc or one of its related companies (WILEY) or their respective licensors, and your interest therein is only that of having possession of and the right to reproduce the Materials pursuant to Section 2 herein during the continuance of this Agreement. You agree that you own no right, title or interest in or to the Materials or any of the intellectual property rights therein. You shall have no rights hereunder other than the license as provided for

above in Section 2. No right, license or interest to any trademark, trade name, service mark or other branding ("Marks") of WILEY or its licensors is granted hereunder, and you agree that you shall not assert any such right, license or interest with respect thereto.

5. NEITHER WILEY NOR ITS LICENSORS MAKES ANY WARRANTY OR REPRESENTATION OF ANY KIND TO YOU OR ANY THIRD PARTY, EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO THE MATERIALS OR THE ACCURACY OF ANY INFORMATION CONTAINED IN THE MATERIALS, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTY OF MERCHANTABILITY, ACCURACY, SATISFACTORY QUALITY, FITNESS FOR A PARTICULAR PURPOSE, USABILITY, INTEGRATION OR NON-INFRINGEMENT AND ALL SUCH WARRANTIES ARE HEREBY EXCLUDED BY WILEY AND ITS LICENSORS AND WAIVED BY YOU.

6. WILEY shall have the right to terminate this Agreement immediately upon breach of this Agreement by you.

7. You shall indemnify, defend and hold harmless WILEY, its Licensors and their respective directors, officers, agents and employees, from and against any actual or threatened claims, demands, causes of action or proceedings arising from any breach of this Agreement by you.

8. IN NO EVENT SHALL WILEY OR ITS LICENSORS BE LIABLE TO YOU OR ANY OTHER PARTY OR ANY OTHER PERSON OR ENTITY FOR ANY SPECIAL, CONSEQUENTIAL, INCIDENTAL, INDIRECT, EXEMPLARY OR PUNITIVE DAMAGES, HOWEVER CAUSED, ARISING OUT OF OR IN CONNECTION WITH THE DOWNLOADING, PROVISIONING, VIEWING OR USE OF THE MATERIALS REGARDLESS OF THE FORM OF ACTION, WHETHER FOR BREACH OF CONTRACT, BREACH OF WARRANTY, TORT, NEGLIGENCE, INFRINGEMENT OR OTHERWISE (INCLUDING, WITHOUT LIMITATION, DAMAGES BASED ON LOSS OF PROFITS, DATA, FILES, USE, BUSINESS OPPORTUNITY OR CLAIMS OF THIRD PARTIES), AND WHETHER OR NOT THE PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION SHALL APPLY NOTWITHSTANDING ANY FAILURE OF ESSENTIAL PURPOSE OF ANY LIMITED REMEDY PROVIDED HEREIN.

9. Should any provision of this Agreement be held by a court of competent jurisdiction to be illegal, invalid, or unenforceable, that provision shall be deemed amended to achieve as nearly as possible the same economic effect as the original provision, and the legality, validity and enforceability of the remaining provisions of this Agreement shall not be affected or impaired thereby.

10. The failure of either party to enforce any term or condition of this Agreement shall not constitute a waiver of either party's right to enforce each and every term and condition of this Agreement. No breach under this agreement shall be deemed waived or excused by either party unless such waiver or consent is in writing signed by the party granting such waiver or consent. The waiver by or consent of a party to a breach of any provision of this Agreement shall not operate or be construed as a waiver of or consent to any other or subsequent breach by such other party.

11. This Agreement may not be assigned (including by operation of law or otherwise) by you without WILEY's prior written consent.
12. Any fee required for this permission shall be non-refundable after thirty (30) days from receipt.
13. These terms and conditions together with CCC's Billing and Payment terms and conditions (which are incorporated herein) form the entire agreement between you and WILEY concerning this licensing transaction and (in the absence of fraud) supersedes all prior agreements and representations of the parties, oral or written. This Agreement may not be amended except in writing signed by both parties. This Agreement shall be binding upon and inure to the benefit of the parties' successors, legal representatives, and authorized assigns.
14. In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall prevail.
15. WILEY expressly reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions.
16. This Agreement will be void if the Type of Use, Format, Circulation, or Requestor Type was misrepresented during the licensing process.
17. This Agreement shall be governed by and construed in accordance with the laws of the State of New York, USA, without regards to such state's conflict of law rules. Any legal action, suit or proceeding arising out of or relating to these Terms and Conditions or the breach thereof shall be instituted in a court of competent jurisdiction in New York County in the State of New York in the United States of America and each party hereby consents and submits to the personal jurisdiction of such court, waives any objection to venue in such court and consents to service of process by registered or certified mail, return receipt requested, at the last known address of such party.

Wiley Open Access Terms and Conditions

All research articles published in Wiley Open Access journals are fully open access: immediately freely available to read, download and share. Articles are published under the terms of the [Creative Commons Attribution Non Commercial License](#), which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes. The license is subject to the Wiley Open Access terms and conditions: Wiley Open Access articles are protected by copyright and are posted to repositories and websites in accordance with the terms of the [Creative Commons Attribution Non Commercial License](#). At the time of deposit, Wiley Open Access articles include all changes made during peer review, copyediting, and publishing. Repositories and

websites that host the article are responsible for incorporating any publisher-supplied amendments or retractions issued subsequently.

Wiley Open Access articles are also available without charge on Wiley's publishing platform, Wiley Online Library or any successor sites.

Use by non-commercial users

For non-commercial and non-promotional purposes individual users may access, download, copy, display and redistribute to colleagues Wiley Open Access articles, as well as adapt, translate, text- and data-mine the content subject to the following conditions:

The authors' moral rights are not compromised. These rights include the right of "paternity" (also known as "attribution" - the right for the author to be identified as such) and "integrity" (the right for the author not to have the work altered in such a way that the author's reputation or integrity may be impugned).

Where content in the article is identified as belonging to a third party, it is the obligation of the user to ensure that any reuse complies with the copyright policies of the owner of that content.

If article content is copied, downloaded or otherwise reused for non-commercial research and education purposes, a link to the appropriate bibliographic citation (authors, journal, article title, volume, issue, page numbers, DOI and the link to the definitive published version on Wiley Online Library) should be maintained. Copyright notices and disclaimers must not be deleted.

Any translations, for which a prior translation agreement with Wiley has not been agreed, must prominently display the statement: "This is an unofficial translation of an article that appeared in a Wiley publication. The publisher has not endorsed this translation."

Use by commercial "for-profit" organisations

Use of Wiley Open Access articles for commercial, promotional, or marketing purposes requires further explicit permission from Wiley and will be subject to a fee. Commercial purposes include:

Copying or downloading of articles, or linking to such articles for further redistribution, sale or licensing;

Copying, downloading or posting by a site or service that incorporates advertising with such content;

The inclusion or incorporation of article content in other works or services (other than normal quotations with an appropriate citation) that is then available for sale or licensing, for a fee (for example, a compilation produced for marketing purposes, inclusion in a sales pack)

Use of article content (other than normal quotations with appropriate citation) by for-profit organisations for promotional purposes

Linking to article content in e-mails redistributed for promotional, marketing or educational purposes;

Use for the purposes of monetary reward by means of sale, resale, licence, loan, transfer or other form of commercial exploitation such as marketing products

Print reprints of Wiley Open Access articles can be purchased from:
corporatesales@wiley.com

Other Terms and Conditions:

BY CLICKING ON THE "I AGREE..." BOX, YOU ACKNOWLEDGE THAT YOU HAVE READ AND FULLY UNDERSTAND EACH OF THE SECTIONS OF AND PROVISIONS SET FORTH IN THIS AGREEMENT AND THAT YOU ARE IN AGREEMENT WITH AND ARE WILLING TO ACCEPT ALL OF YOUR OBLIGATIONS AS SET FORTH IN THIS AGREEMENT.

v1.7

If you would like to pay for this license now, please remit this license along with your payment made payable to "COPYRIGHT CLEARANCE CENTER" otherwise you will be invoiced within 48 hours of the license date. Payment should be in the form of a check or money order referencing your account number and this invoice number RLNK500932350.

Once you receive your invoice for this order, you may pay your invoice by credit card. Please follow instructions provided at that time.

Make Payment To:

Copyright Clearance Center

Dept 001

P.O. Box 843006

Boston, MA 02284-3006

For suggestions or comments regarding this order, contact RightsLink Customer Support:

customercare@copyright.com or +1-877-622-5543 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing \$0 in the Total field) are free. Please retain this printable license

for your reference. No payment is required.

Paper 2

JOHN WILEY AND SONS LICENSE TERMS AND CONDITIONS

Dec 12, 2012

This is a License Agreement between Mary Claessen ("You") and John Wiley and Sons ("John Wiley and Sons") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by John Wiley and Sons, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3032821108045
License date	Nov 19, 2012
Licensed content publisher	John Wiley and Sons
Licensed content publication	International Journal of Language & Communication Disorders
Book title	None
Licensed content author	Mary Claessen, Suze Leitão, Nick Barrett
Licensed content date	Dec 31, 2010
Start page	411
End page	423
Type of use	Dissertation/Thesis
Requestor type	Author of this Wiley article
Format	Print and electronic
Portion	Full article
Will you be translating?	No
Order reference number	None
Total	0.00 USD

Terms and Conditions

TERMS AND CONDITIONS This copyrighted material is owned by or exclusively licensed to John Wiley & Sons, Inc. or one of its group companies (each a "Wiley Company") or a society for whom a Wiley Company has exclusive publishing rights in relation to a particular journal (collectively WILEY"). By clicking "accept" in connection with completing this licensing transaction, you agree that the following terms and conditions apply to this transaction (along with the billing and payment terms and conditions established by the Copyright Clearance Center Inc., ("CCC's Billing and Payment terms and conditions"), at the time that you opened your Rightslink account (these are available at any time at <http://myaccount.copyright.com>) Terms and Conditions 1. The materials you have requested permission to reproduce (the "Materials") are protected by copyright. 2. You are hereby granted a personal, non-exclusive, non-sublicensable, non-transferable, worldwide, limited license to reproduce the Materials for the purpose specified in the licensing process. This license is for a one-time use only with a maximum distribution equal to the number that you identified in the licensing process. Any form of republication granted by this licence must be completed within two years of the

date of the grant of this licence (although copies prepared before may be distributed thereafter). The Materials shall not be used in any other manner or for any other purpose. Permission is granted subject to an appropriate acknowledgement given to the author, title of the material/book/journal and the publisher. You shall also duplicate the copyright notice that appears in the Wiley publication in your use of the Material. Permission is also granted on the understanding that nowhere in the text is a previously published source acknowledged for all or part of this Material. Any third party material is expressly excluded from this permission.

3. With respect to the Materials, all rights are reserved. Except as expressly granted by the terms of the license, no part of the Materials may be copied, modified, adapted (except for minor reformatting required by the new Publication), translated, reproduced, transferred or distributed, in any form or by any means, and no derivative works may be made based on the Materials without the prior permission of the respective copyright owner. You may not alter, remove or suppress in any manner any copyright, trademark or other notices displayed by the Materials. You may not license, rent, sell, loan, lease, pledge, offer as security, transfer or assign the Materials, or any of the rights granted to you hereunder to any other person.

4. The Materials and all of the intellectual property rights therein shall at all times remain the exclusive property of John Wiley & Sons Inc or one of its related companies (WILEY) or their respective licensors, and your interest therein is only that of having possession of and the right to reproduce the Materials pursuant to Section 2 herein during the continuance of this Agreement. You agree that you own no right, title or interest in or to the Materials or any of the intellectual property rights therein. You shall have no rights hereunder other than the license as provided for above in Section 2. No right, license or interest to any trademark, trade name, service mark or other branding ("Marks") of WILEY or its licensors is granted hereunder, and you agree that you shall not assert any such right, license or interest with respect thereto.

5. NEITHER WILEY NOR ITS LICENSORS MAKES ANY WARRANTY OR REPRESENTATION OF ANY KIND TO YOU OR ANY THIRD PARTY, EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO THE MATERIALS OR THE ACCURACY OF ANY INFORMATION CONTAINED IN THE MATERIALS, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTY OF MERCHANTABILITY, ACCURACY, SATISFACTORY QUALITY, FITNESS FOR A PARTICULAR PURPOSE, USABILITY, INTEGRATION OR NON-INFRINGEMENT AND ALL SUCH WARRANTIES ARE HEREBY EXCLUDED BY WILEY AND ITS LICENSORS AND WAIVED BY YOU.

6. WILEY shall have the right to terminate this Agreement immediately upon breach of this Agreement by you.

7. You shall indemnify, defend and hold harmless WILEY, its Licensors and their respective directors, officers, agents and employees, from and against any actual or threatened claims, demands, causes of action or proceedings arising from any breach of this Agreement by you.

8. IN NO EVENT SHALL WILEY OR ITS LICENSORS BE LIABLE TO YOU OR ANY OTHER PARTY OR ANY OTHER PERSON OR ENTITY FOR ANY SPECIAL, CONSEQUENTIAL, INCIDENTAL, INDIRECT, EXEMPLARY OR PUNITIVE DAMAGES, HOWEVER CAUSED, ARISING OUT OF OR IN CONNECTION WITH THE DOWNLOADING, PROVISIONING, VIEWING OR USE OF THE MATERIALS REGARDLESS OF THE FORM OF ACTION, WHETHER FOR BREACH OF CONTRACT, BREACH OF WARRANTY, TORT, NEGLIGENCE, INFRINGEMENT OR OTHERWISE (INCLUDING, WITHOUT LIMITATION, DAMAGES BASED ON LOSS OF PROFITS, DATA, FILES, USE, BUSINESS OPPORTUNITY OR CLAIMS OF THIRD PARTIES), AND WHETHER OR NOT THE PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION SHALL APPLY NOTWITHSTANDING ANY FAILURE OF ESSENTIAL PURPOSE OF ANY LIMITED REMEDY PROVIDED HEREIN.

9. Should any provision of this Agreement be held by a court of competent jurisdiction to be illegal, invalid, or unenforceable, that provision shall be deemed amended to achieve as nearly as possible the same economic effect as the original provision, and the legality, validity and enforceability of the remaining provisions of this Agreement shall not be affected or impaired thereby.

10. The failure of either party to enforce any term or condition of this Agreement shall not constitute a waiver of either party's right to enforce each and every term and condition of this Agreement. No breach under this agreement shall be deemed waived or excused by either party unless such waiver or consent is in writing signed by the party granting such waiver or consent. The waiver by or consent of a party to a breach of any provision of this Agreement shall not operate or be construed as a waiver of or consent to any other or subsequent breach by such other party.

11. This Agreement may not be assigned (including by operation of law or otherwise) by you without WILEY's prior written consent.

12. Any fee required for this permission shall be non-refundable after thirty (30) days from receipt.

13. These terms and conditions together with CCC's Billing and Payment terms and conditions (which are incorporated herein) form the entire agreement between you and WILEY concerning this licensing transaction and (in the absence of fraud) supersedes all prior agreements and representations of the parties, oral or written. This Agreement may not be

amended except in writing signed by both parties. This Agreement shall be binding upon and inure to the benefit of the parties' successors, legal representatives, and authorized assigns. 14. In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall prevail. 15. WILEY expressly reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions. 16. This Agreement will be void if the Type of Use, Format, Circulation, or Requestor Type was misrepresented during the licensing process. 17. This Agreement shall be governed by and construed in accordance with the laws of the State of New York, USA, without regards to such state's conflict of law rules. Any legal action, suit or proceeding arising out of or relating to these Terms and Conditions or the breach thereof shall be instituted in a court of competent jurisdiction in New York County in the State of New York in the United States of America and each party hereby consents and submits to the personal jurisdiction of such court, waives any objection to venue in such court and consents to service of process by registered or certified mail, return receipt requested, at the last known address of such party.

Wiley Open Access Terms and Conditions All research articles published in Wiley Open Access journals are fully open access: immediately freely available to read, download and share. Articles are published under the terms of the [Creative Commons Attribution Non Commercial License](#), which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes. The license is subject to the Wiley Open Access terms and conditions: Wiley Open Access articles are protected by copyright and are posted to repositories and websites in accordance with the terms of the [Creative Commons Attribution Non Commercial License](#). At the time of deposit, Wiley Open Access articles include all changes made during peer review, copyediting, and publishing. Repositories and websites that host the article are responsible for incorporating any publisher-supplied amendments or retractions issued subsequently. Wiley Open Access articles are also available without charge on Wiley's publishing platform, **Wiley Online Library** or any successor sites.

Use by non-commercial users For non-commercial and non-promotional purposes individual users may access, download, copy, display and redistribute to colleagues Wiley Open Access articles, as well as adapt, translate, text- and data-mine the content subject to the following conditions:

The authors' moral rights are not compromised. These rights include the right of "paternity" (also known as "attribution" - the right for the author to be identified as such) and "integrity" (the right for the author not to have the work altered in such a way that the author's reputation or integrity may be impugned).

Where content in the article is identified as belonging to a third party, it is the obligation of the user to ensure that any reuse complies with the copyright policies of the owner of that content.

If article content is copied, downloaded or otherwise reused for non-commercial research and education purposes, a link to the appropriate bibliographic citation (authors, journal, article title, volume, issue, page numbers, DOI and the link to the definitive published version on Wiley Online Library) should be maintained. Copyright notices and disclaimers must not be deleted.

Any translations, for which a prior translation agreement with Wiley has not been agreed, must prominently display the statement: "This is an unofficial translation of an article that appeared in a Wiley publication. The publisher has not endorsed this translation."

Use by commercial "for-profit" organisations

Use of Wiley Open Access articles for commercial, promotional, or marketing purposes requires further explicit permission from Wiley and will be subject to a fee. Commercial purposes include:

Copying or downloading of articles, or linking to such articles for further redistribution, sale or licensing;

Copying, downloading or posting by a site or service that incorporates advertising with such content;

The inclusion or incorporation of article content in other works or services (other than normal quotations with an appropriate citation) that is then available for sale or licensing, for a fee (for

example, a compilation produced for marketing purposes, inclusion in a sales pack)

Use of article content (other than normal quotations with appropriate citation) by for-profit organisations for promotional purposes

Linking to article content in e-mails redistributed for promotional, marketing or educational purposes;

Use for the purposes of monetary reward by means of sale, resale, licence, loan, transfer or other form of commercial exploitation such as marketing products

Print reprints of Wiley Open Access articles can be purchased from: corporatesales@wiley.com

Other Terms and Conditions:

BY CLICKING ON THE "I AGREE..." BOX, YOU ACKNOWLEDGE THAT YOU HAVE READ AND FULLY UNDERSTAND EACH OF THE SECTIONS OF AND PROVISIONS SET FORTH IN THIS AGREEMENT AND THAT YOU ARE IN AGREEMENT WITH AND ARE WILLING TO ACCEPT ALL OF YOUR OBLIGATIONS AS SET FORTH IN THIS AGREEMENT.

v1.7

If you would like to pay for this license now, please remit this license along with your payment made payable to "COPYRIGHT CLEARANCE CENTER" otherwise you will be invoiced within 48 hours of the license date. Payment should be in the form of a check or money order referencing your account number and this invoice number RLNK500900767. Once you receive your invoice for this order, you may pay your invoice by credit card. Please follow instructions provided at that time. Make Payment To: Copyright Clearance Center Dept 001 P.O. Box 843006 Boston, MA 02284-3006 For suggestions or comments regarding this order, contact RightsLink Customer Support: customercare@copyright.com or +1-877-622-5543 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing \$0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.



RightsLink®

Home

Account
Info

Help



Title: Phonological representations in children with SLI:
Author: Mary Claessen, Suze Leitão
Publication: Child Language Teaching and Therapy
Publisher: Sage Publications
Date: May 2, 2012
Copyright © 2012, SAGE Publications

Logged in as:
Mary Claessen
Account #:
3000595401

LOGOUT

Redirected Request

If you are an Author inquiring about the re-use of your journal article, please note that after publication of the journal article, Authors may re-use their content in any later work written or edited by the Author or for the Author's classroom use, without seeking permission from SAGE. For any other use of your work, please contact the publisher. For additional information see www.sagepub.com/repository/binaries/journals/permissions/author_use.doc.

BACK

CLOSE WINDOW

Copyright © 2012 [Copyright Clearance Center, Inc.](http://www.copyright.com) All Rights Reserved. [Privacy statement](#).
Comments? We would like to hear from you. E-mail us at customercare@copyright.com

Paper 5

INFORMA HEALTHCARE LICENSE TERMS AND CONDITIONS

Dec 12, 2012

This is a License Agreement between Mary Claessen ("You") and Informa Healthcare ("Informa Healthcare") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by Informa Healthcare, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3046390403455
License date	Dec 12, 2012
Licensed content publisher	Informa Healthcare
Licensed content publication	International Journal of Speech-Language Pathology
Licensed content title	The relationship between stored phonological representations and speech output
Licensed content author	Mary Claessen, Suze Leitão
Licensed content date	Jun 1, 2012
Volume number	14
Issue number	3
Start Page	226
End Page	234
Type of Use	Dissertation/Thesis
Requestor type	Author
Format	print and electronic
Portion	Full article
Will you be translating?	No
Number of copies	50
Order reference number	None

Title of your thesis / dissertation	Phonological processing skills in Specific language impairment
Expected completion date	Mar 2013
Estimated Size (pages)	120
Total	0.00 USD

Terms and Conditions

Informa Healthcare: Terms and Conditions for reuse of Figures, Tables, Questionnaires, Images, Excerpts, Full Article/Chapter in a Thesis/Dissertation

Informa Healthcare (or a company within the group of which Informa Healthcare forms a part) is the publisher of the Journal/Book. The material you have licensed (hereafter "Material") was published in the Journal/Book and Informa Healthcare has the right, title and authority to grant licenses for the use of the Material.

- . Informa Healthcare grants You license to use the Material on the terms set out in this license (hereafter "License"). Informa Healthcare reserve all rights not expressly granted in this License.
- . This License is non-exclusive, revocable, worldwide and personal to You.
- . This permission authorization is valid for a period of 12 months commencing from the date as specified in the order details and is granted strictly according to the details of use specified in the order details.
- . This License is granted for the lifetime of one edition of the Thesis/Dissertation up to the production run figure as specified in the order details, as applicable, only. You agree further editions require a further license.
- . The Material is licensed to You in hard copy, reprinted, format only for academic study, research and evaluation purposes only. Your educational institution is permitted to deposit one electronic version in a their Institutional Repository. You shall ensure that use in that Institutional Repository is password protected.
- . You are permitted to distribute the quantity ordered to third parties for use under the terms of this License but otherwise no rights are granted to any third party and You will not assign, transfer, sub-license or otherwise deal with Your rights and obligations under this License.
- . All rights in the Material (including, without limitation, copyright and all other intellectual property rights), remain the sole and exclusive property of Informa Healthcare.
- . This permission does not cover any third party copyrighted work which may appear in the material requested or articles where Informa Healthcare does not control the copyright.
- . Full citation shall be given by you in the reference list or bibliography of the Thesis/Dissertation and an acknowledgment in the following format shall follow each table or figure legend where reproduced separately from the full article: [Author], [Book title], [Edition], copyright © [Year of publication], Informa Healthcare. Reproduced with permission of Informa Healthcare Or [Author], [Journal title], [Year; Volume (Issue): page range], copyright © [Year of publication], Informa Healthcare. Reproduced with permission of Informa Healthcare
- . No alterations may be made to our work without written consent. Where alterations are made the citation shall read as follows: [Author], [Book title], [Edition], copyright © [Year of publication], Informa Healthcare. Adapted with permission of Informa Healthcare Or [Author], [Journal title], [Year; Volume (Issue): page range], copyright © [Year of publication], Informa Healthcare. Adapted with permission of Informa Healthcare.
- . You will pay any cost detailed above (hereafter " License Fee") in accordance with the Terms and Conditions of CCC. The grant of this License is conditional upon full payment by You of the License Fee. Whilst you may exercise the rights licensed immediately upon the grant of this License, this License will be automatically revoked if you do not pay the License Fee as required.
- . In the event that You breach any of the terms of this License and fail to remedy such breach (if the same is capable of remedy) within 14 days of receiving written notice of the breach, Informa Healthcare will be entitled to terminate this License with immediate effect. You shall cease all use of the Material if this License is revoked or terminated. Any continued use of the Material after revocation or termination will be a breach of the rights (including, without limitation,

- intellectual property rights) of Informa Healthcare.
- . You shall indemnify Informa and keep it fully indemnified against any claims, losses, damages, costs, expenses (including reasonable legal expenses) or other liability incurred by it in respect of any infringement of its rights (including intellectual property rights) arising from Your use of the Material in breach of this license.
 - . You have requested a license to use the Material. You are deemed to have full knowledge of the Material and Informa Healthcare will not be liable for:
 - any loss of revenue, profit, data, information: or
 - for Your use or inability to use the Material; or
- for any indirect, special or consequential damages arising in connection with the License or the Material, even if Informa Healthcare has been advised of the possibility of such damages.
- . Informa Healthcare's liability to You in contract, tort (including negligence) or otherwise in relation to this License is limited to the License Fee. However, Informa Healthcare does not exclude or limit liability for fraud or for death or personal injury resulting from its negligence.
 - . The publication contains information from reputable sources and although reasonable efforts have been made to publish accurate information, Informa Healthcare makes no warranties (either express or implied) as to the accuracy or fitness for a particular purpose of the information or advice contained herein. Informa Healthcare wishes to make it clear that any views or opinions expressed in the publication by individual authors or contributors are their personal views and opinions and do not necessarily reflect the views/opinions of Informa Healthcare.
 - . To the extent that any information or guidance contained in this publication is intended for use by medical professionals, it shall serve strictly as a supplement to the medical professional's own judgement, knowledge of the patient's medical history, relevant manufacturer's instructions and the appropriate best practice guidelines. Because of the rapid advances in medical science, any information or advice on dosages, procedures, or diagnoses should be independently verified. The publication does not indicate whether a particular treatment is appropriate or suitable for a particular individual. Ultimately it is the sole responsibility of the medical professional to make his or her own professional judgements, so as appropriately to advise and treat patients. Save for death or personal injury caused by the Informa Healthcare's negligence and to the fullest extent otherwise permitted by law, neither Informa Healthcare nor any person engaged or employed by Informa Healthcare shall be responsible or liable for any loss, injury or damage caused to any person or property arising in any way from the use granted herein.
 - . Permission is granted by Copyright Clearance Center Inc (CCC) on Informa Healthcare's behalf and by agreeing to the terms and conditions listed above you also agree to CCC's additional terms and conditions as the administrators of this licensing service, these terms and conditions are agreed to as a condition of establishing an account and may be seen at any time at <http://myaccount.copyright.com>. Should any inconsistency exist between Informa Healthcare Terms and Conditions and CCC's additional terms and conditions, this License shall prevail, but only to the extent of the inconsistency.
 - . This Agreement is the whole agreement between You and Informa Healthcare and supersedes any previous agreement relating to the Material. You acknowledge and agree that in entering into this Agreement You shall not rely on, and shall have no remedy in respect of, any statement, representation, warranty or understanding (whether negligently or innocently made) other than as expressly set out in this Agreement as a warranty.
 - . This License is governed by English law and You and Informa Healthcare submit to the exclusive jurisdiction of the Courts of England and Wales.
 - . On termination of this Agreement, the following clauses shall remain in force: 1, 8, 14-18, 20-22.
 - . Other Terms and Conditions:
- v1.0

If you would like to pay for this license now, please remit this license along with your payment made payable to "COPYRIGHT CLEARANCE CENTER" otherwise you will be invoiced within 48 hours of the license date. Payment should be in the form of a check or money order referencing your account number and this invoice number RLNK500915814. Once you receive your invoice for this order, you may pay your invoice by credit card. Please follow instructions provided at that time. Make Payment To: Copyright Clearance Center Dept 001 P.O. Box 843006 Boston, MA 02284-3006 For suggestions or comments regarding this order, contact

RightsLink Customer Support: customercare@copyright.com or +1-877-622-5543 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing \$0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.

Bibliography

Aguilar-Mediavella, E., Sanz-Torrent, T., & Serra-Raventos, M. (2002). A comparative study of the phonology of pre-school children with specific language impairment (SLI), language delay (LD) and normal acquisition. *Clinical linguistics and phonetics*, *16*(8), 573-596. doi: 10.1080/02699200210148394

Alt, M., & Plante, E. (2006). Factors that influence lexical and semantic fast mapping of young children with specific language impairment. *Journal of Speech and Hearing Research*, *49*(5), 941-954. doi: 10.1044/1092-4388(2006/068)

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4 ed.). Washington, DC: American Psychiatric Association.

Anthony, J., Williams, J., Aghara, R., Dunkelberger, M., Noval, M., & Mukherjee, A. (2010). Assessment of individual differences in phonological representation. *Reading and writing*, *23*(8), 969-994. doi: 10.1007/s11145-009-9185-7

Archibald, L., & Gathercole, S. (2006). Short term and working memory in specific language impairment. *International Journal of Language and Communication Disorders*, *41*(6), 675-693. doi: 10.1080/13682820500442602

Baker, E., Croot, K., Mcleod, S., & Paul, R. (2001). Psycholinguistic models of speech development and their application to clinical practice. *Journal of Speech, Language and Hearing Research*, *44*(3), 685-702. doi: 10.1044/1092-4388(2001/055)

Baker, E., & Munro, N. (2011). An overview of resources for assessing toddlers' productions of polysyllables. *Acquiring Knowledge in Speech, Language and Hearing*, *13*(2), 58-63. doi:<http://www.speechpathologyaustralia.org.au/publications/jcpslp>

Bishop, D., & Snowling, M. (2004). Developmental Dyslexia and Specific Language Impairment: Same or Different? *Psychological Bulletin*, *130*(6), 858-886. doi: 10.1037/0033-2909.130.6.858

Boada, R., & Pennington, B. (2006). Deficient implicit phonological representations in children with dyslexia. *Journal of Experimental Child Psychology*, *95*, 153-193. doi: 10.1016

Botting, N., & Conti-Ramsden, G. (2001). Non-word repetition and language development in children with specific language impairment (SLI). *International Journal of Communication Disorders*, *36*(4), 421-432. doi: 10.1080/13682820110074971

Carroll, J. & Myers, J. (2011). Spoken word classification in children and adults. *Journal of Speech, Language and Hearing Research*, *54* (2) 127-147. doi:10.1044/1092-4388(2010/08-0148)

Carroll, J., & Snowling, M. (2004). Language and phonological skills in children at high risk of reading difficulties. *Journal of Child Psychology and Psychiatry*, *45*(3) 631-640. DOI: 10.1111/j.1469-7610.2004.00252.x

Carroll, J. M., Snowling, M., Hulme, C., & Stevenson, J. (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, *39*(5), 913-923. doi: 10.1037/0012-1649.39.5.913

Catts, H., Adlof, S. M., Hogan, T. P., & Ellis Weismer, S. (2005). Are Specific Language Impairment and Dyslexia Distinct Disorders? . *Journal of Speech, Language, and Hearing Research*, *48*(6), 1378-1396. doi: 10.1044/1092-4388(2005/096

Catts, H., Fey, M., Zhang, X., & Tomblin, B. (2001). Estimating the risk of future reading difficulties in kindergarten children: A research-based model and its clinical implementation.

Language, Speech & Hearing Services in Schools., 32(1), 38-50. doi:10.1044/0161-1461(2001/004)

Catts, H., Gillespie, M., Leonard, L., Kail, R., & Miller, C. (2002). The role of speed of processing, rapid naming and phonological awareness in reading achievement. *Journal of Learning Disabilities*, 35(6), 509-524. doi: 10.1037/0022-0663.95.3.453

Catts, H., & Kamhi, A. (1999). *Language and Reading Disabilities*. Boston: Allyn and Bacon.

Chiat, S. (2000). *Understanding Children with Language Problems*. Cambridge: Cambridge University Press.

Chiat, S. (2001). Mapping theories of developmental language impairment: Premises, predictions and evidence. *Language and Cognitive Processes*, 16(2/3), 113-142. doi: 10.1080/01690960042000012

Claessen, M., Heath, S., Fletcher, J., Hogben, J., & Leitão, S. (2009). Quality of phonological representations: A window into the lexicon? *International Journal of Language & Communication Disorders*, 44(2), 121-144. doi: 10.1080/13682820801966317

Claessen, M., & Leitao, S. (2004). *Phonological representations: a window into the lexicon*. Paper presented at the 26th World Congress of the International Association of Logopedics and Phoniatics, Queensland.

Claessen, M., & Leitão, S. (2012). Phonological representations in children with SLI. *Child Language Teaching and Therapy* 28(2), 211-223. doi: 10.1177/0265659012436851

Claessen, M., & Leitão, S. (2012). The relationship between stored phonological representations and speech output. *International Journal of Speech-Language Pathology* 14(3), 226-234. doi: 10.3109/17549507.2012.679312

Claessen, M., Leitão, S., & Barrett, N. (2010). Investigating children's ability to reflect on stored phonological representations: the Silent Deletion of Phonemes Task. *International Journal of Language & Communication Disorders*, 45(4), 411-423. doi: 10.1080/13682820903111945

Claessen, M., Leitão, S., Kane, R., & Williams, C. (in press). Phonological processing skills in Specific Language Impairment. *International Journal of Speech - Language Pathology*.

[Coady, J. & Aslin, R. \(2004\)](#). Young children's sensitivity to probabilistic phonotactics in the developing lexicon. *Journal of Experimental Child Psychology*, 89, 183-213. doi: 10.1016/j.jecp.2004.07.004.

Constable, A. (2001). A Psycholinguistic Approach to Word-finding Difficulties. In J. Stackhouse & B. Wells (Eds.), *Children's Speech and Literacy Difficulties 2: Identification and intervention* (pp. 330-365). London: Whurr.

Conti-Ramsden, G., Botting, N., & Faragher, B. (2001). Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 42(6), 741-748. doi: 10.1111/1469-7610.00770

Conti-Ramsden, G., Botting, N., Simkin, Z., & Knox, E. (2001). Follow-up of children attending infant language units: outcomes at 11 years of age. *International Journal of Language and Communication Disorders*, 36(2), 207-219. doi: 10.1080/13682820121213

Conti-Ramsen, G., Crutchley, A., & Botting, N. (1997). The extent to which psychometric tests differentiate subgroups of children with SLI. *Journal of Speech, Language and Hearing Research, 40*(4), 765-777. doi: <http://jslhr.asha.org>

Crosbie, S., Dodd, B., & Howard, D. (2002). Spoken word comprehension in children with SLI: A comparison of three case studies. *Child Language Teaching and Therapy, 18*(3), 190-212. doi: 10.1191/0265659002ct235oa

Dodd, B. (1995). *The differential diagnosis and treatment of children with speech disorder*. London: Whurr Publishers.

Dodd, B. & Gillon, G. (2001). Exploring the relationship between phonological awareness, speech impairment and literacy. *Advances in Speech-Language Pathology, 3*(2) doi: 10.3109/14417040109003720

Dollaghan, C. (1998). Spoken word recognition in children with specific language impairment. *Applied Psycholinguistics, 19*(193-207). doi: <http://dx.doi.org/10.1017/S0142716400010031>

Dollaghan, C., & Campbell, T. (1998). Nonword Repetition and Child Language Impairment. *Journal of Speech, Language, and Hearing Research, 41*(5), 1136-1146. doi: <http://jslhr.asha.org>

Edwards, J., Beckman, M., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability: Effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language and Hearing Research, 47*(2) 421-436. doi:10.1044/1092-4388(2004/034

Edwards, J., & Lahey, M. (1998). Nonword repetitions of children with specific language impairment: Exploration of some explanations for their inaccuracies. *Applied psycholinguistics*, 19(2), 279-309. doi: <http://dx.doi.org/10.1017/S0142716400010079>

Elbro, C. (1998). When reading is "readn" or somthn. Distinctness of phonological representations of lexical items in normal and disabled readers. *Scandinavian Journal of Psychology*, 39, 149-153. doi: 10.1111/1467-9450.393070

Elbro, C., Borstrom, I., & Petersen, D. K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, 33(1), 36-60. doi: 10.1598/RRQ.33.1.3

Ellis Weismer, S. E., Evans, J., & Hesketh, L. J. (1999). An Examination of Verbal Working Memory Capacity in Children With Specific Language Impairment. *Journal Of Speech Language and Hearing Research*, 42, 1249-1260. doi: <http://jslhr.asha.org>

Ellis Weismer, S. E., Tomblin, B., Zhang, X., Buckwalter, P., Chynoweth, J., & Jones, M. (2000). Nonword repetition performance in school-aged children with and without language impairment. *Journal of Speech, Language and Hearing Research*, 43(4), 865-878.
doi: <http://jslhr.asha.org>

Fawcett, A. & Nicolson, R. (1994). Naming speed in children with dyslexia. *Journal of Learning Disabilities* 27(10), 641-646. doi: 10.1177/002221949402701004

Felton, R., & Brown, I. (1990). Phonological processes as predictors of specific reading skills in children at risk for reading failure. *Reading and Writing: An Interdisciplinary Journal*, 2(1), 39-59. doi: <http://link.springer.com/journal/11145>

Fisher, C., Hunt, C., Chambers, K., & Church, B. (2001). Abstraction and Specificity in Preschoolers' Representations of Novel Spoken Words. *Journal of Memory and Language*, 45, 665-687. doi: org/10.1006/jmla.2001.2794

Fowler, A. (1991). How early phonological development might set the stage for phoneme awareness. In S. Brady & D. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* (pp. 97-117). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Foy, J. & Mann, V. (2009). Effects of onset density in preschool children: Implications for development of phonological awareness and phonological representation. *Applied Psycholinguistics*, 30 (2), 339-361. doi:10.1017/S0142716409090146

Fredrickson, N., Frith, U., & Reason, R. (1997). *Phonological Assessment Battery*: NFER-Nelson.

Gathercole, S. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied psycholinguistics*, 27, 513-543. doi: 10.1017/S0142716406060383

Gathercole, S., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, 29, 336-360. doi: 10.1016/0749-596X(90)90004

Gaulin, C., & Campbell, T. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual and Motor Skills*, 79, 55-64. doi: 10.2466/pms.1994.79.1.55

Gillon, G. (2002a). Follow-up study investigating the benefits of phonological awareness intervention for children with spoken language impairment. *International Journal of*

Language and Communication Disorders, 37(4), 381-400. doi:

10.1080/1368282021000007776

Gillon, G. (2002b). Phonological Awareness Intervention for Children: From the Research Laboratory to the Clinic. *the Asha leader online* Retrieved August 12th, 2004, from <http://www.asha.org/about/publications/leader-online/archives/2002/q4/021203a.htm>

Gillon, G. (2004). *Phonological awareness: From research to practice*. New York: The Guilford Press.

Graf Estes, K., Evans, J. L., & Else-Quest, N. L. (2007). Differences in the Nonword Repetition Performance of Children With and Without Specific Language Impairment: A Meta-Analysis. *Journal of Speech, Language, and Hearing Research.*, 50(1), 177-196. doi: 10.1044/1092-4388(2007/015)

Gray, S. (2005). Word learning by preschoolers with specific language impairment: Effect of phonological or semantic cues. *Journal of Speech, Language, and Hearing Research*, 48(6), 1452-1467. doi: 10.1044/1092-4388(2005/101)

Gray, S., & Brinkley, S. (2011). Fast mapping and word learning by pre-schoolers with specific language impairment in a supported learning context: Effect of encoding cues, phonotactic probability and object familiarity. *Journal of Speech, Language and Hearing Research*, 54(3), 870-884. doi: 10.1044/1092-4388(2010/09-0285)

Griffiths, Y., & Snowling, M. (2001). Auditory word identification and phonological skills in dyslexic and average readers. *Applied Psycholinguistics*, 22(3), 419-439. doi: <http://dx.doi.org/>

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Perception and Psychophysics*, 28(267-283). doi: 10.3758/BF03204386

Heath, S., Claessen, M., Fletcher, J., Hogben, J., & Leitao, S. (2006). *Catch them before they fall: Cost effective identification of students at-risk for literacy problems*. Paper presented at the Speech Pathology Australia National Conference, Fremantle, Western Australia.

Heath, S., Fletcher, J., & Hogben, J. (2006). *Catch them before they fall 2003-2005; Cost effective screening for children at-risk for literacy literacy problems*. (Report to the Department of Education and Training, Western Australia). Perth, WA: The University of Western Australia.

Heath, S., & Hogben, J. (2004). Cost-effective prediction of reading difficulties *Journal of Speech, Language, and Hearing Research*, 47(4), 751-765. doi: <http://jslhr.asha.org>

Hesketh, A. (2001). Phonological awareness, Speech Impairment and Literacy: The missing link. *Advances in Speech Language Pathology*, 3(2), 155-158.

doi:10.3109/14417040109003722

Hesketh, A. (2010). Metaphonological intervention: Phonological awareness therapy. In L. Williams, S. McLeod & R. McCauley (Eds.), *Intervention for speech sound disorders in children* (pp. 247-274). Baltimore, MD: Brookes.

Hewlett, N., Gibbon, F., & Cohen-McKenzie. (1997). When is a velar an alveolar? Evidence supporting a revised psycholinguistic model of speech production in children. *International Journal of Communication Disorders*, 33(2), 161-176. doi: 10.1080/136828298247811

Hogan, T., Catts, H., & Little, T. (2005). The relationship between phonological awareness and reading: Implications for the assessment of phonological awareness. *Language, Speech & Hearing Services in Schools*, 36(4), 285-293. doi: 10.1044/0161-1461(2005/029)

Joanisse, M., & Seidenberg, M. (1998). Specific language impairment: a deficit in grammar or processing? *Trends in Cognitive Sciences*, 2(7), 240-247. doi: 10.1016/S1364-6613(98)01186-3

Kail, R., & Hall, L. (1994). Processing speed, naming speed and reading. *Developmental Psychology*, 30(6), 949-954. doi: 10.1037/0012-1649.30.6.949

Kan, P., & Windsor, J. (2010). Word learning in children with primary language impairment: A meta-analysis. *Journal of Speech, Language and Hearing Research*, 53(3), 739-756. doi: 10.1044/1092-4388(2009/08-0248)

Kay, J., Lesser, R., & Colt. (1996). Psycholinguistic assessments of language processing in aphasia (PALPA): An introduction. *Aphasiology*, 10(2), 159-180. doi: 10.1080/02687039608248403

Leitão, S. (2003). Angela's story: Applying psycholinguistic principles to spelling and word learning. *ACQuiring knowledge in speech, language and hearing*, 5(3), 114-117. doi: <http://www.speechpathologyaustralia.org.au/publications/jcpslp>

Leitão, S., & Fletcher, J. (2004). Literacy outcomes for students with speech impairment: long-term follow-up. *International Journal of Communication Disorders*, 39(2), 245-256. doi: 10.1080/13682820310001619478

Leitão, S., Fletcher, J., & Hogben, J. (2000). Speech impairment and literacy difficulties: Underlying links. *Australian Educational and Developmental Psychologist*, 17(1), 63-75. doi: 108868

Leonard, L. (1998). *Children with Specific Language Impairment*. Massachusetts: MIT.

Leonard, L., Weismer, S., Miller, C., Francis, D., Tomblin, B., & Kail, R. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech and Hearing Research*. doi: 10.11044/1092-4388(2007.029)

Liberman, I., & Shankweiler, D. (1985). Phonology and the problems of learning to read and write. *Remedial and Special Education*, 6(6), 8-17. doi: 10.1177/074193258500600604

Locke, J. (1980). The Inference of Speech Perception in the Phonologically Disordered Child. *Journal of Speech and Hearing Disorders*, 431-467.

doi: <http://jshd.asha.org/cgi/content/abstract/45/4/431>

Lonigan, C. J., Burgess, C. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent variable longitudinal study. *Developmental Psychology*, 36(5), 596-613. doi: 10.1037/0012-1649.36.5.596

Maillart, C., Schelstraete, M., & Hupet, M. (2004). Phonological Representations in Children With SLI: A Study of French. *Journal of Speech, Language, and Hearing Research*, 47(1), 187-198. doi: 10.1044/1092-4388(2004/016)

Mani, N., & Plunkett, K. (2007). Phonological specificity of vowels and consonants in early lexical representations. *Journal of Memory and Language*, 57, 252-272. doi: org/10.1016/j.jml.2007.03.005

Manis, F., McBride-Chang, C., Seidenberg, M., P, K., Doi, L., & Munson, B. (1997). Are speech perception deficits associated with developmental dyslexia? *Journal of Experimental Child Psychology*, 66, 211-235. doi: org.dbgw.lis.curtin.edu.au/10.1006/jecp.1997.2383

Marshall, C., Ramus, F., & van der Lely, H. (2010). Do children with dyslexia and/or specific language impairment compensate for place assimilation? Insight into phonological grammar

and representations. *Cognitive Neuropsychology*, 27(7), 563-586. doi:

10.1080/02643294.2011.588693

Marshall, C., & van der Lely, H. (2009). Effects of word position and stress on onset cluster production: Evidence from typical development, specific language impairment and dyslexia.

Language 85(1), 39-57. doi: 10.1353/lan.0.0081

Marton, K., & Schwartz, R. G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, 46, 1138-1153. doi: 10.1044/1092-4388(2003/089

Research, 46, 1138-1153. doi: 10.1044/1092-4388(2003/089

Metsala, J., & Walley, A. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J.

Metsala & L. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89-120). London:

Lawrence Erlbaum Associates.

Miller, C. A., Kail, R., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech Language and Hearing Research*, 44, 416-433. doi:

10.1044/1092-4388(2001/034)

Monsell, S. (1987). On the relation between lexical input and output pathways for speech. In

A. Allport (Ed.), *Language Perception and Production* (pp. 273-311). London: Academic Press.

Montgomery, J., Magimairaj, B., & Finney, M. (2010). Working memory and specific language impairment: An update on the relation and perspectives on assessment and

treatment. *American Journal of Speech-Language Pathology*, 19, 78-94. doi: 10.1044/1058-

0360(2009/09-0028)

Montgomery, J. W. (1999). Recognition of Gated Words by Children with Specific Language Impairment: An Examination of Lexical Mapping. [Research Support, U.S. Gov't, P.H.S.].

Journal of Speech, Language and Hearing Research, 42(3), 735-743.

doi: <http://jslhr.asha.org/cgi/content/abstract/42/3/735>

Munson, B., Edwards, J., & Beckman, M. E. (2005). Relationships Between Nonword Repetition Accuracy and Other Measures of Linguistic Development in Children With Phonological Disorders. *Journal of Speech, Language and Hearing Research*, 48(1), 61-78.

doi: doi:10.1044/1092-4388(2005/006)

Nathan, L., Stackhouse, J., Goulandris, N., & Snowling, M. J. (2004). The Development of Early Literacy Skills Among Children With Speech Difficulties: A Test of the "Critical Age Hypothesis". *Journal of Speech, Language, and Hearing Research*, 47(2), 377-392. doi:

10.1044/1092-4388(2004/031)

Neilson, R. (2003a). *Astronaut invented spelling test*. Jamberoo, NSW: Westonprint.

Neilson, R. (2003b). *Sutherland Phonological Awareness Test - Revised*. Jamberoo, NSW: Language Speech and Literacy Services.

Pennington, B. (2006). From single to multiple deficit models of developmental disorders. . *Cognition*, 101, 383-413. doi: 10.1016

Pennington, B., & Bishop, D. (2009). Relations among speech, language and reading disorders. *Annual review of psychology*, 60(1), 283-306. doi:

10.1146/annurev.psych.60.110707.163548

Petrucelli, N., Bavin, E. & Bretherton, L. (2012) Children with specific language impairment and resolved late talkers: working memory profiles at 5 years. *Journal of Speech, Language and Hearing Research*, 55 (6) 1690 – 1703. doi: 10.1044/1092-4388(2012/11-0288

Pring, T. (2005). *Research Methods in Communication Disorders*. London: Whurr.

Rees, R. (2001). Principles of psycholinguistic intervention. In J. Stackhouse & B. Wells (Eds.), *Children's Speech and Literacy Difficulties 2: Identification and intervention* (pp. 41-65). London: Whurr.

Rice, M., & Wexler, K. (1996). Toward Tense as a Clinical Marker of Specific Language Impairment in English-Speaking Children. *Journal of Speech and Hearing Research*, 39, 1239-1257. doi: <http://jslhr.asha.org/cgi/content/abstract/39/6/1239>

Roy, P., & Chiat, S. (2008). Beyond outcomes: the importance of developmental pathways In B. Joffe, M. Cruice & S. Chiat (Eds.), *Language disorders in children and adults*. (pp. 1-19). West Sussex: Wiley-Blackwell.

Rvachew, S., Nowak, M., & Cloutier, G. (2004). Effect of Phonemic Perception Training on the Speech Production and Phonological Awareness Skills of Children With Expressive Phonological Delay. *American Journal of Speech - Language Pathology*, 13(3), 250-263. doi: 10.1044/1058-0360(2004/026)

Schwartz, R. (2009). Specific Language Impairment. In R. Schwartz (Ed.), *Handbook of child language disorders*. New York: Psychology Press.

Semel, E., Wiig, E., & Secord, W. (2003a). *Clinical Evaluation of Language Fundamentals - IV*: The Psychological Corporation. Harcourt Brace Jovanovich, Inc.

Semel, E., Wiig, E., & Secord, W. (2003b). *Clinical Evaluation of Language Fundamentals - Fourth Edition Examiner's Manual*. Marickville: Harcourt Assessment.

Sheng, L., & McGregor, K. (2010). Lexical-semantic organisation in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, 53(1), 146-159. doi: 10.1044/1092-4388(2009/08-0160)

Shriberg, L., Austin, D., Lewis, B., McSweeney, J., & Wilson, D. (1997). The percentage of consonants correct (PCC) Metric: Extensions and reliability data. *Journal of Speech, Language and Hearing Research*, 40, 708-722. doi: <http://jslhr.asha.org/cgi/content/abstract/40/4/708>

Snowling, M. (2000a). *Dyslexia*. Oxford: Blackwell publishers.

Snowling, M. (2000b). Language and literacy skills: Who is at risk and why? In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 245-260). Hove, UK: Psychology Press

Snowling, M., & Hulme, C. (1994). The development of phonological skills. *Phil Trans R Soc London B*, 346, 21-27. doi: 10.1098/rstb.1994.0124

Snowling, M., van Wagendonk, B., & Stafford, C. (1988). Object-naming deficits in developmental dyslexia. *Journal of Research in Reading*, 11(2), 67-85. doi: 10.1111/j.1467-9817.1988.tb00152.x

Stackhouse, J. (2000). Barriers to literacy development in children with speech and language difficulties. In D. Bishop & L. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 73-97). Hove, UK: Psychology Press.

Stackhouse, J., Vance, M., Pascoe, M., & Wells, B. (2007). *Compendium of Auditory and Speech Tasks. Children's Speech and Literacy Difficulties*. West Sussex: John Wiley & Sons.

Stackhouse, J., & Wells, B. (1997a). *Children's Speech and Literacy Difficulties, A Psycholinguistic Framework*. London: Whurr.

Stackhouse, J., & Wells, B. (1997b). How do speech and language problems affect literacy development ? In C. Hulme & M. Snowling (Eds.), *Dyslexia: Biology, cognition and intervention* (pp. 182-211). London: Whurr Publishers Ltd.

Sutherland, D., & Gillon, G. (2005). Assessment of phonological representations in children with speech impairment. *Language Speech and Hearing Services in Schools, 36*(4), 294-310. doi: 10.1044/0161-1461(2005/030)

Sutherland, D., & Gillon, G. (2007). Development of phonological representations and phonological awareness in children with speech impairment. *International Journal of Language and Communication Disorders, 42*(2), 229 - 250. doi: 10.1080/13682820600806672

Swan, D., & Goswami, G. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology, 66*, 18-41. doi: 10.1006/jecp.1997.2375

Torgesen, J., Wagner, R., & Rashotte, C. (1994). Longitudinal studies of phonological processing and reading. *Journal of Learning Disabilities, 27*(5), 276-286. doi: 10.1177/002221949402700503

Van der Lely, H., Rosen, S., & McClelland, A. (1998). Evidence for a grammar-specific deficit in children. *Current Biology, 8*(23), 1253-1258. doi: 10.1016/S0960-9822(07)00534-9

Vance, M., Stackhouse, J., & Wells, B. (2005). Speech Production Skills in Children aged 3-7 years. *International Journal of Language & Communication Disorders*, 40(1), 29-48. doi: 10.1080/13682820410001716172

Vanderwalle, E., Boets, B., Ghesquiere, P., & Zink, I. (2010). Who is at risk for dyslexia? Phonological processing in five-to-seven-year old Dutch speaking children with SLI. *Scientific studies of reading*, 14(1), 58-84. doi: 10.1080/10888430903242035

Vellutino, F., Fletcher, J., Snowling, M., & Scanlon, D. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, 45(1), 2-40. doi: 10.1046/j.0021-9630.2003.00305.x

Vitevich, M. S., & Luce, P. A. (1999). Probabilistic Phonotactics and Neighbourhood Activation in Spoken Word Recognition. *Journal of Memory and Language*, 40(3), 374-408. doi: <http://www.journals.elsevier.com/journal-of-memory-and-language/>

Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101(2), 192-212. doi: 10.1037/0033-2909.101.2.192

Wagner, R., Torgesen, J., & Rashotte, C. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, 30(1), 73-87. doi: <http://www.apa.org>

Wagner, R., Torgesen, J., & Rashotte, C. (1999). *Comprehensive Test of Phonological Processing*. Austin: Pro-Ed.

Walley, A. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review, 13*, 286-350.

Doi: [10.1006/drev.1993.1015](https://doi.org/10.1006/drev.1993.1015)

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children - Third Revision*. New York: The Psychological Corporation.

Wechsler, D. (2004). *Wechsler Preschool and Primary Scale of Intelligence - Third Edition*. Cleveland: Psychological Corporation.

Wesseling, R., & Reitsma, P. (2001). Preschool phonological representations and development of reading skills. *Annals of Dyslexia, 51*, 203-229. doi: 10.1007/s11881-001-0011-4

Westwood, P. (1993). The South Australian spelling test. In Department for Education and Children's Services (Ed.), *Spelling*. Seacombe Gardens: Department for Education and Children's Services.

White, K., & Morgan, J. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language, 59*, 114-132.

Wolf, M., & Bowers, G. (1999). The Double-Deficit Hypothesis for the Developmental Dyslexias. *Journal of Educational Psychology, 91*(3), 415-438. doi: <http://www.apa.org/pubs/journals/edu/index.aspx>

Woodcock, R. (1987). *Woodcock Reading Mastery Test -Revised*. New York: American Guidance Service.

Zirou, F., Ecalle, J., Magnan, A & Sanchez, M (2010). The fragile nature of phonological awareness in children with specific language impairment: Evidence from literacy

development. *Child Language Teaching and Therapy* 26 (3), 347-358. Doi:

10.1177/0265659010369288